MIT'S MAGAZINE OF INNOVATION

TECHNOLOGY REVIEW

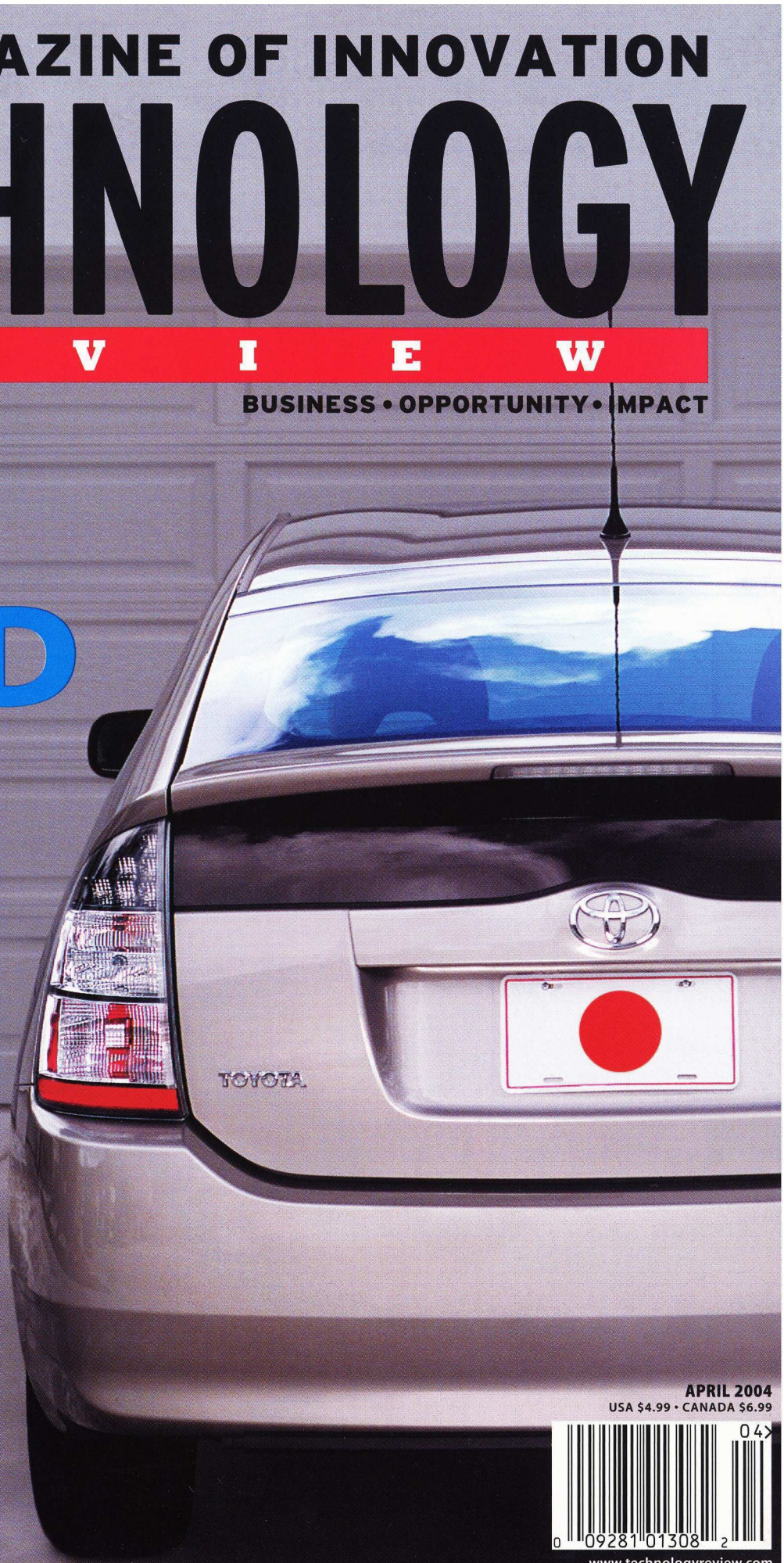
BUSINESS • OPPORTUNITY • IMPACT

WHY YOUR NEXT CAR WILL BE A HYBRID

HOW TOYOTA SET THE STANDARD FOR A NEW AUTO ERA: POWERFUL CARS THAT TOP 50 MPG

SOCIAL NETWORKING

ANOTHER DOT.BOMB OR THE REAL DEAL?



PLUS:

THE HOTTEST VC ON THE PLANET

NEW HOPE FOR FIGHTING MALARIA

CAN THE U.S. SAVE ITS HIGH-TECH JOBS?

APRIL 2004
USA $4.99 • CANADA $6.99

04

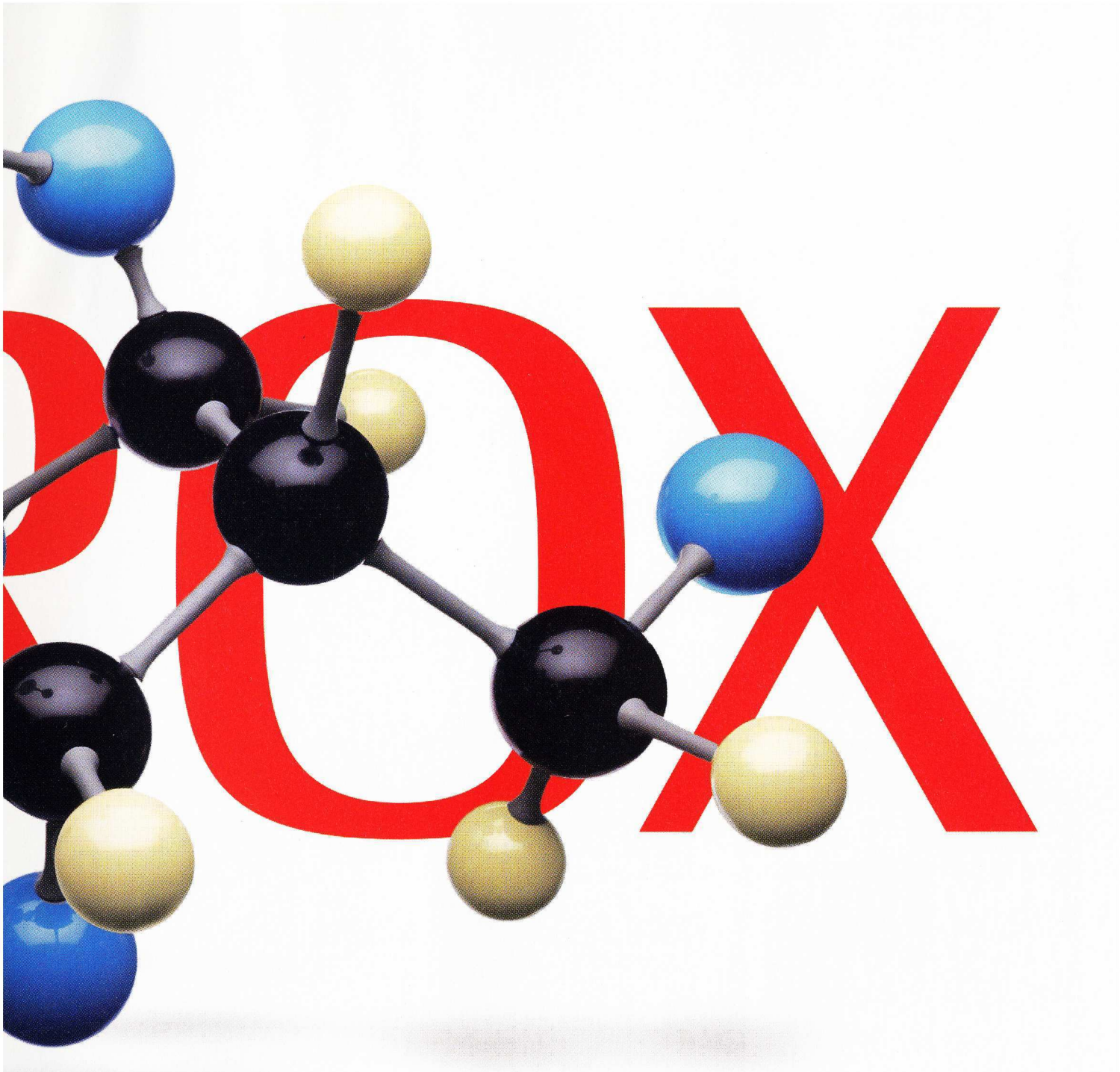
0 09281 01308 2

www.technologyreview.com

technology
review
Published by MIT

The Dow Chemical Company's archives held 5.5 million minutes instead of days, they turned to Xerox for

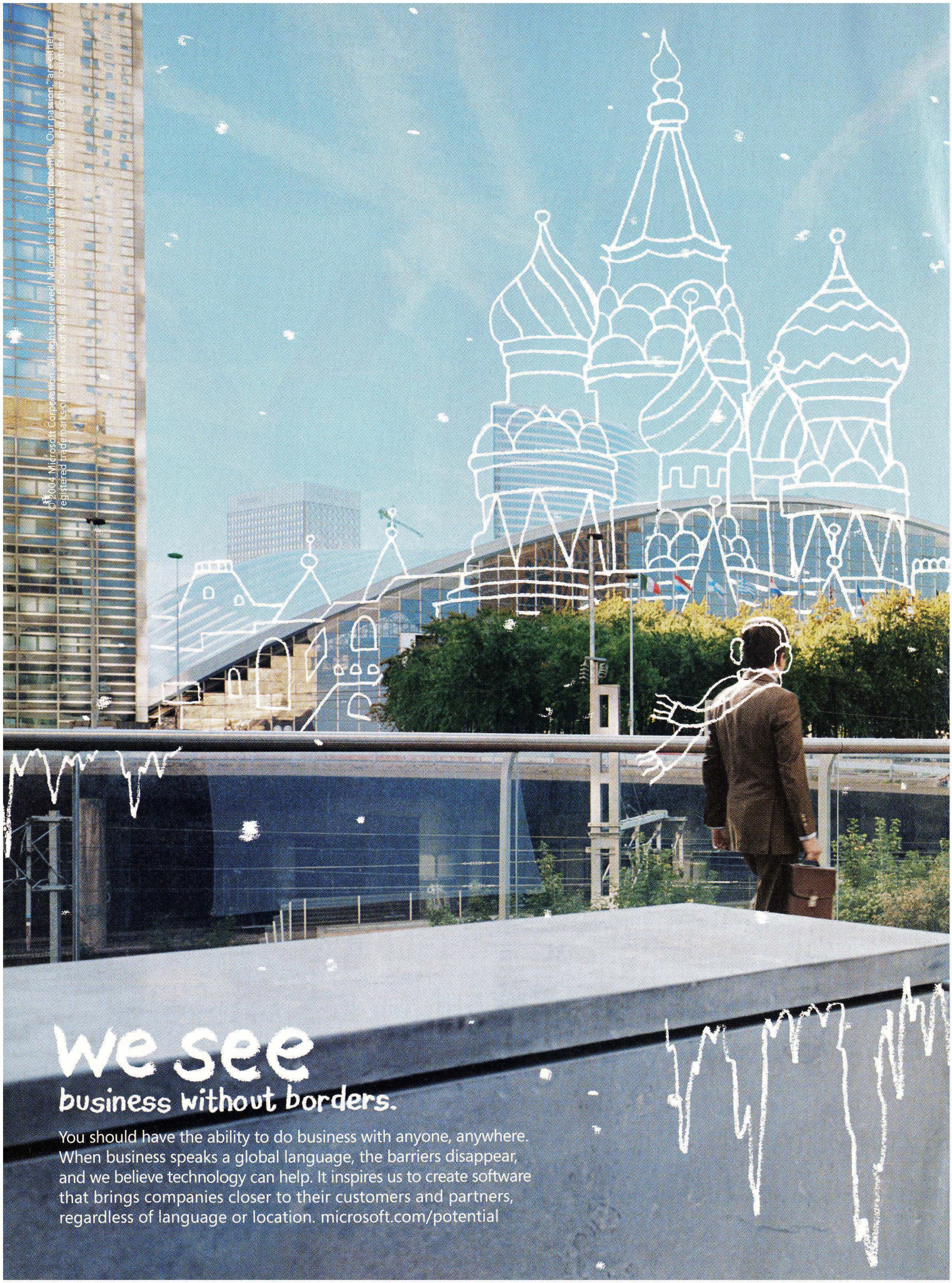
Learn more: www.xerox.com/learn **For a sales rep: 1-800-ASK-XEROX ext. LEARN**



pages of R&D. To help researchers access them in the correct formula. There's a new way to look at it.

THE DOCUMENT COMPANY

XEROX®




Your potential. Our passion.™
Microsoft

CONTENTS

COVER STORY

FEATURES

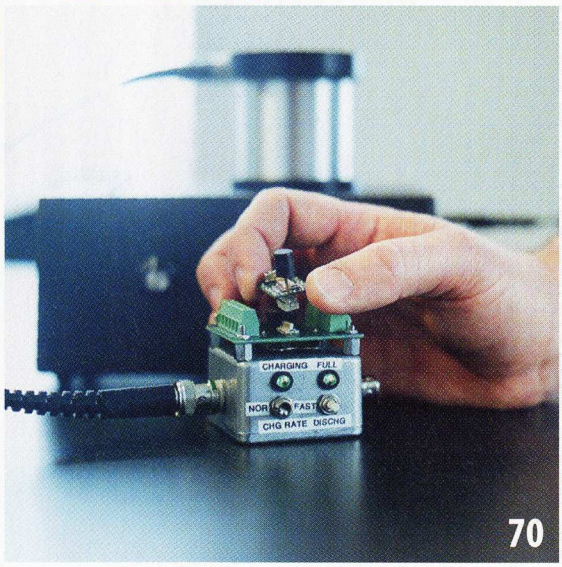
Cover photograph by Diana Koenigsberg

DEPARTMENTS

Technology Review
Volume 107, Number 3
April 2004

"When people see what a powerful hybrid can do, it's going to rattle a few cages." —*Robert Stempel, p. 36*

56



70

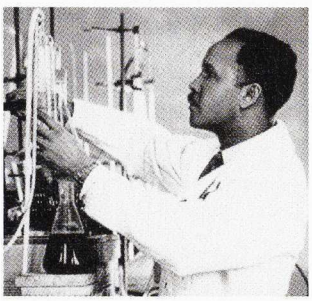
IN EVERY ISSUE

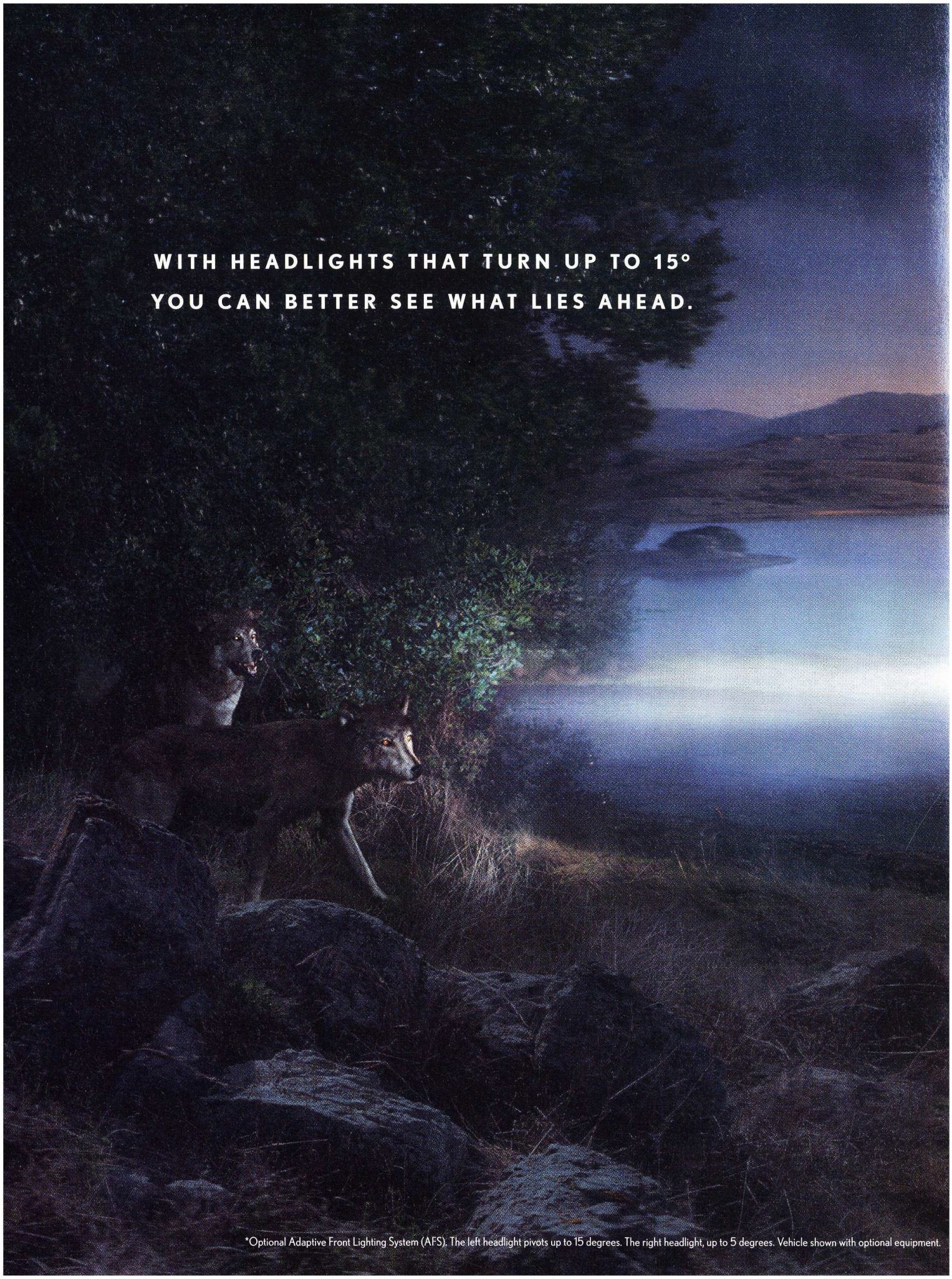
COLUMNS

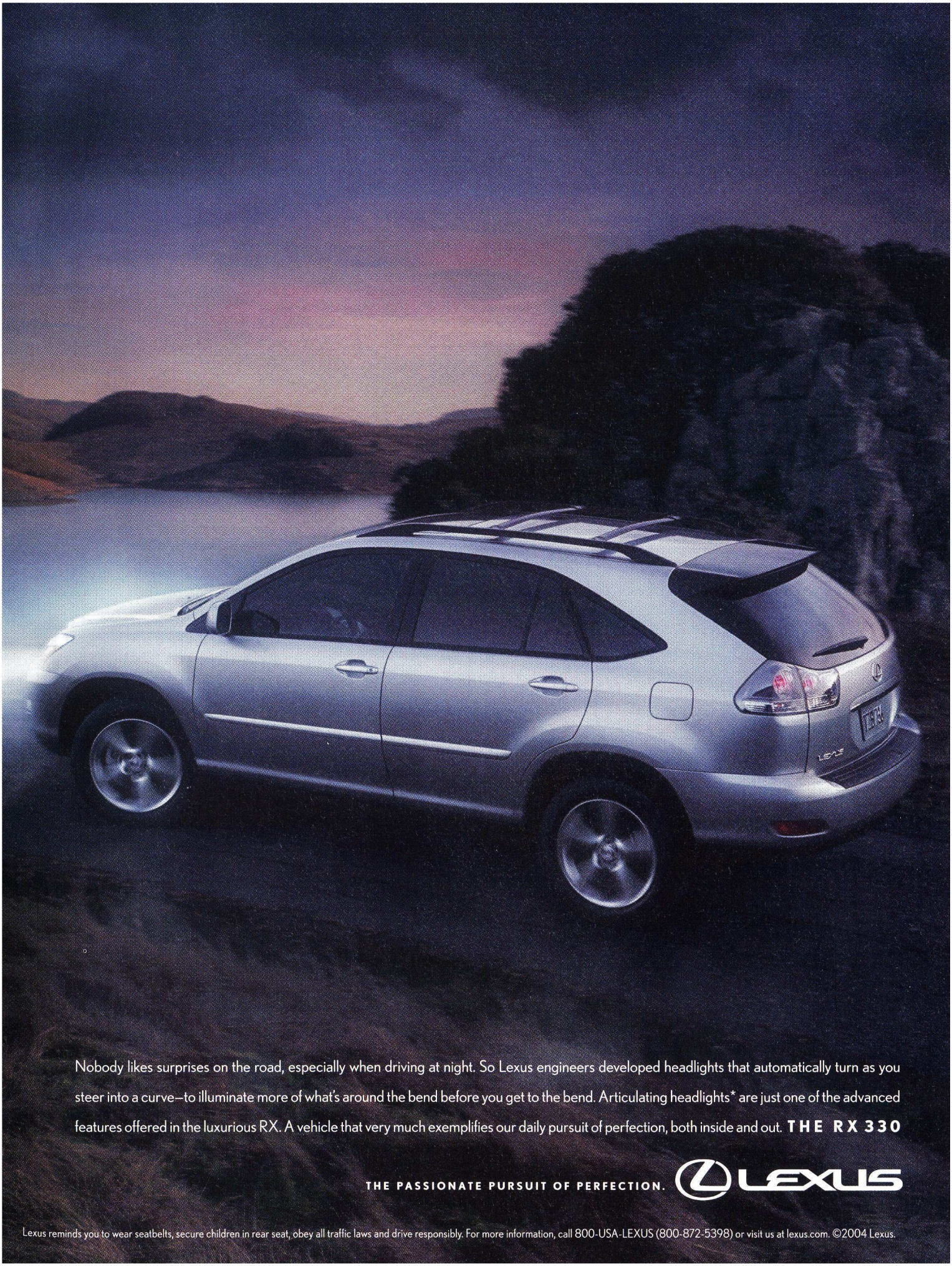
FEATURED ONLINE

▪ Animated "Visualize" graphic ▪ Web log with commentary by MIT faculty and *TR* contributors ▪ Forums for discussing *TR* articles ▪ Weekly polls ▪ And more...

www.technologyreview.com




WITH HEADLIGHTS THAT TURN UP TO 15°
YOU CAN BETTER SEE WHAT LIES AHEAD.
*Optional Adaptive Front Lighting System (AFS). The left headlight pivots up to 15 degrees. The right headlight, up to 5 degrees. Vehicle shown with optional equipment.



Nobody likes surprises on the road, especially when driving at night. So Lexus engineers developed headlights that automatically turn as you steer into a curve—to illuminate more of what's around the bend before you get to the bend. Articulating headlights* are just one of the advanced features offered in the luxurious RX. A vehicle that very much exemplifies our daily pursuit of perfection, both inside and out. **THE RX 330**

THE PASSIONATE PURSUIT OF PERFECTION. LEXUS

Lexus reminds you to wear seatbelts, secure children in rear seat, obey all traffic laws and drive responsibly. For more information, call 800-USA-LEXUS (800-872-5398) or visit us at lexus.com. ©2004 Lexus.

Finally, My Last Conventional Car

IRAQI FORCES ROLLED INTO KUWAIT IN AUGUST 1990, and probably because I was the newest mid-level editor, I became de facto energy editor of *BusinessWeek*. What followed was a rash of stories about oil, natural gas, and U.S. dependence on fossil fuels. That led to articles about conservation and alternative energy—and, inevitably, to cars. ▪ Then, as now, internal-combustion-engine vehicles consumed a huge percentage of all fossil fuel burned in the United States. We wrote about electric cars and other technologies that promised to wean Americans of their gas-guzzling ways. When I bought a new car in January 1992, less than a year after the Gulf War ended, I told my friends it was the last conventionally powered vehicle I would ever own.

I was off by one car. There was just no proven, competitive, and readily available alternative to the conventional internal-combustion engine a few years ago, when I bought my next (and present) vehicle. But as writer Peter Fairley makes clear in this month's cover story—"Hybrids' Rising Sun," page 34—that is no longer true. Whether I buy my next car in eight years or eight months, I am sure to have a viable choice. My next car will equal or surpass the performance of the one I drive now, spare the environment from tons of pollutants and greenhouse-gas emissions, and with double the fuel efficiency, save me several thousand dollars over its operational life. My next car, of course, will be a gasoline-electric hybrid.

My next car will spare the environment tons of pollutants and save thousands of dollars over its life.

A hybrid car, which uses both a gasoline engine and an electric motor for propulsion, can deliver 50 to 60 miles per gallon. Some 130,000 Prius hybrids will roll off Toyota's assembly lines this year. On the way are hybrid versions of the Lexus luxury sedan and the Highlander SUV. The company estimates that by 2006, hybrid sales could hit 300,000. Honda is not far behind, and General Motors last year announced that it would have the capability to build as many as one million hybrids by 2007. While such offerings will total a small percentage of overall vehicle sales, they could make a noticeable dent in U.S. oil consumption. And as Fairley reports, if we could somehow boost the average mileage of all U.S. vehicles to 40 miles per gallon, we would save three million barrels of oil a day—more than we import from the Middle East.

Many people see hybrids as a steppingstone on the way to even more radical changes in what we drive. The buzz right now is around the hydrogen-fuel-cell-powered car—under research and development at several automakers—which would burn no fossil fuels directly and produce no harmful emissions.

But while car companies and politicians get PR mileage out of promising such advances, I've learned to be skeptical about how fast a big change like that will come, since it will take a compelling shift in the economics of hydrogen to convince carmakers to speed things up. But I do know that I can finally keep my promise. **Robert Buderi**

NEXT MONTH

MAY 2004 SPECIAL ISSUE: THE NEW ERA OF INVENTION

Reinventing Invention
Where do the best ideas for new products and businesses come from? You just might be surprised by the answer. There's a resurgence in the influence of inventors and renewed recognition of the vital role invention plays in commercializing new technologies.

Where Is Woz?
Nearly 30 years after he designed the first Apple computer, Steve Wozniak is at it again—this time hoping to reinvent wireless technology.

Directed Sound
The ability to beam audio to a specific spot in space could change how you think about sound. Inventors Elwood "Woody" Norris and F. Joseph Pompei are vying to make it happen.

Microsoft's Magic Pen
In Microsoft's bustling Beijing lab, inventor Jian Wang has built a digital pen that could rewrite computer interfaces.

Five Killer Patents
Technology Review's annual pick of the five most important patents issued the previous year provides a sneak preview of the key technologies that will drive new businesses and markets and change the way you get things done.

Global Patent Map
The revival in invention is a worldwide phenomenon, as this map detailing the national origins of 2003 U.S. patents illustrates.

***TR*'s Annual Patent Scorecard**
We rank more than 100 companies on their 2003 patent performance. And the winner is…

SHE'S CALLING FOR THE WORLD AT THE TOUCH OF A BUTTON.

WE'RE ANSWERING.

It's a world of homes and offices, people, machines and other living things. It's a seamlessly interconnected world for our customers and our business partners — all powered by NTT DoCoMo. We're Japan's leading mobile communications provider, and our vision of such a world drives our innovations. From mobile e-commerce that will bring consumers closer to their cash or credit, wherever they roam. To digital fingerprints that will revolutionize ticketing to amusement parks and other paid destinations — and forever change the way people gather information on the run. For a closer look at how NTT DoCoMo is delivering tomorrow's communications today, visit www.nttdocomo.com

NTT DoCoMo

WIRELESS W 2004 CTIA

Visit us at CTIA Hall B3, Booth 2357

MIT'S MAGAZINE OF INNOVATION

TECHNOLOGY REVIEW

EDITOR IN CHIEF
Robert Buderi

EXECUTIVE EDITOR	David Rotman
DEPUTY EDITOR/WEB EDITOR	Herb Brody
MANAGING EDITOR	Tracy Staedter
ART DIRECTOR	Linda Koury
SENIOR EDITORS	Sally Atwood, Wade Roush, David Talbot, Rebecca Zacks
ASSOCIATE EDITORS	Gregory T. Huang, Corie Lok, Lisa Scanlon
DESIGN ASSOCIATE	John Sheppard
COPY CHIEF	Larry Hardesty
FACT CHECKER	Dan Cho
PRODUCTION MANAGER	Valerie V. Kiviat
EDITORIAL ASSISTANT	Alyssa Danigelis

CONTRIBUTING EDITOR
Erika Jonietz

CONTRIBUTING WRITERS
Ivan Amato, Rodney Brooks, Joe Chung, Jon Cohen, Peter Fairley, David H. Freedman, Simson Garfinkel, Michael A. Hiltzik, David Kushner, Charles C. Mann, Michael Schrage, Evan I. Schwartz, Seth Shulman, Gary Taubes, Claire Tristram, M. Mitchell Waldrop

CONTRIBUTING PHOTO EDITOR
Alicia D'Annolfo

TECHNOLOGY REVIEW BOARD
Reid Ashe, Allan S. Bufferd, Jerome I. Friedman, Alice P. Gast, William J. Hecht, R. Bruce Journey, Robert M. Metcalfe, DuWayne J. Peterson Jr., Ann J. Wolpert

TR RELAUNCH FUND

MILLENNIAL PATRON	Robert M. Metcalfe
CENTENNIAL PATRONS	Steve Kirsch, DuWayne J. Peterson Jr.

CUSTOMER SERVICE/SUBSCRIPTION INQUIRIES
NATIONAL 800-877-5230 **INTERNATIONAL** 386-447-6352
www.technologyreview.com/customerservice
Cost $34 per year. Canada residents add $10; other foreign countries add $30.

PERMISSIONS	978-750-8400 www.technologyreview.com/customerservice/permissions.asp
REPRINTS	717-399-1900 ext. 118 technologyreview@reprintbuyer.com or www.technologyreview.com/customerservice/reprints.asp
ADDRESS CHANGES	www.technologyreview.com/custserv/addresschange MIT Records 617-253-8270 (alums only)

TECHNOLOGY REVIEW
One Main Street, 7th Floor, Cambridge MA 02142
TEL 617-475-8000 **FAX** 617-475-8043 www.technologyreview.com

In Spain, "technology" has a capital M

Madrid is the place where Spanish creativity and advanced European technology come together. A region with state-of-the-art electronics, utilities and telecommunications industries, major investments in R&D and highly skilled professionals. Here you will find innovation, quality and competitiveness with capital letters.

Madrid
The capital of innovative Europe.

Feria de Madrid
MADRID TRADE FAIR
The most effective
Business Centre
www.ifema.es
www.simo.ifema.es
www.matelec.ifema.es

Cámara Madrid
www.camaramadrid.es

MIT'S MAGAZINE OF INNOVATION
TECHNOLOGY REVIEW

IEEE is RESEARCH.

Scott has the freedom to conduct research his way, thanks to IEEE.

The IEEE Member Digital Library was designed for individual researchers like Scott. With easy access to the best current technology publications – including top-cited journals and cutting-edge conferences – Scott can find the research he needs, at a price he can afford.

Updated weekly, and with over 1 million online IEEE documents to explore, the IEEE Member Digital Library brings Scott the ability to succeed on his own. He also found papers from three new conferences to help support his research.

To Scott, IEEE is research. Discover what IEEE can be for you.

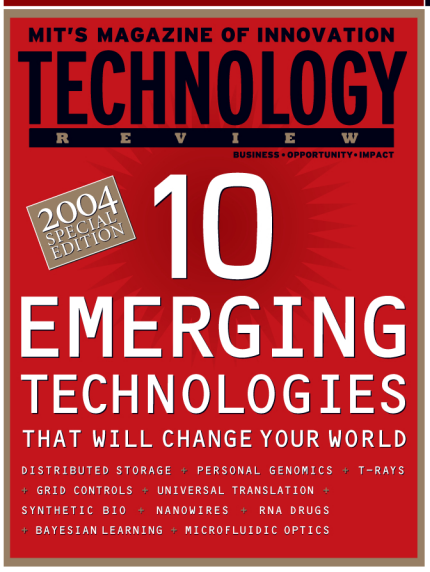
Go here.

www.ieee.org/discover

IEEE

IEEE MEMBER DIGITAL LIBRARY

IEEE INFORMATION DRIVING INNOVATION



WORLD-CHANGING TECHNOLOGIES

I ADMIRE LEADERS LIKE YUQING GAO in "Universal Translation" and Daphne Koller in "Bayesian Machine Learning" for their thinking ("10 Emerging Technologies That Will Change Your World," *TR* February 2004). I am pleased to see computer scientists contributing to major advances in linguistics and genetics. Perhaps Gao's team at IBM could benefit from Daphne Koller's insights and techniques. Could Gao use Koller's Bayesian tools to systematically analyze the myriads of existing translated texts, in several languages at once, to enrich the context and semantic rules as well as translation patterns in her language database? I am looking forward to a time when I can talk to my computer, in any language.

M. I. Motyl-Szary
Westborough, MA

I FOUND TWO OF THE 10 SPOTlighted technologies unsettling. "Bayesian Machine Learning" seems a little too much like artificial intelligence for my taste. A search engine that can take data and make inferences about it and then offer recommendations is a scary start to limiting the necessity of humans. And RNAi therapy would make bioweapons even more deadly. Imagine changing someone's cells so that they won't have blood clots or so the cells don't bring oxygen to the brain as they should.

Chase DiMarco
Henderson, NV

"I am looking forward to a time when I can talk to my computer, in any language."

VOTING WITHOUT PAPER

YOUR Q&A WITH DAVID DILL ("VALID Voting," *TR* February 2004), in which he expresses concern about direct-recording electronic voting machines, is timely. Fairfax County, VA, purchased 1,000 of these machines and used them last November. I was an election officer and can attest that the experience was a disaster. In addition to poor human-interface design, many of the Windows-based machines froze up and needed to be rebooted—during voting. Equipping each machine with a printer would increase paper and machine costs tremendously, reward the vendor for a defective, unverifiable design, reduce system reliability, and lead to a paper-processing nightmare during a recount. Simple precinct-based optical scanners are looking better and better.

Raoul Drapeau
Vienna, VA

THROW OUT YOUR WALLET

WHAT DO YOU GRAB ON YOUR WAY out the door? Michael Schrage, in his article on "Virally Interactive Pixels" (*TR* February 2004), ignored an opportunity to integrate product functionality. Use the key-chain memory device to hold camera phone data and to interface to a PC, but take it off the key chain and glue it to the phone. Take the car-lock fob off the key chain, glue that to the phone as well, and make it programmable through the phone keypad. Let's also make the house key a phone-mounted infrared remote and then throw the key chain away. Put credit card and ID info into the phone and then throw the wallet away. In years to come, humans will carry around exactly one electrified information accessory.

Walker Sloan
Berlin, MA

ROBOTIC TAKEOVER

I WAS PLEASED TO SEE *TR* RAISING environmental concerns around nanotechnology, but I was less pleased to read Rodney Brooks's column on the arrival of robotics ("The Robots Are Here," *TR* February 2004). Brooks champions the salvation from migrant workers that robotics can bring, but he does not address the issues raised for those displaced workers. He also advocates robotics for solving the problem of caring for elderly people, but I shudder at the thought of relying on machines as caregivers during my declining years. Technologists and entrepreneurs need to take a global view when promoting new technology. Even the technologies that promise medical benefits have social and environmental costs.

Nancy Nangeroni
North Reading, MA

IMPROVING AUTOMOTIVE DIAGNOSTICS

AS SOMEONE WHO DOES PROFESSIONAL fleet maintenance, I read with great interest and sympathy Simson Garfinkel's column "Deciphering Cars" (*TR* February 2004). Getting diagnostic trouble codes is relatively easy, but procuring the service bulletins that help a technician track down problems is a challenge. Most manufacturers closely guard these bulletins, so consumers have little chance of obtaining one and will be told to bring the vehicle in for service instead. Any change that yields easier, low-cost diagnostics outside of the dealer shop can't come along soon enough.

Greg Betzel
River Falls, WI

HOW TO CONTACT US

E-MAIL letters@technologyreview.com
WRITE *Technology Review*, One Main Street, 7th Floor, Cambridge MA 02142
FAX 617-475-8043

Please include your address, telephone number, and e-mail address. Letters may be edited for both clarity and length. To discuss our articles online, click on Forums at www.technologyreview.com.

OPERATE PROACTIVELY. Can your network make decisions? Can it see two moves ahead? Anticipate your needs? Resolve its own issues? Defuse problems before they happen? AT&T designs user-centered networks that intelligently monitor events across systems and applications, resulting in faster diagnosis and automatic restoration. Which adds up to less downtime for your mission-critical applications, and more time for your IT department to think about other things. **CAN YOUR NETWORK DO THIS?**

AT&T

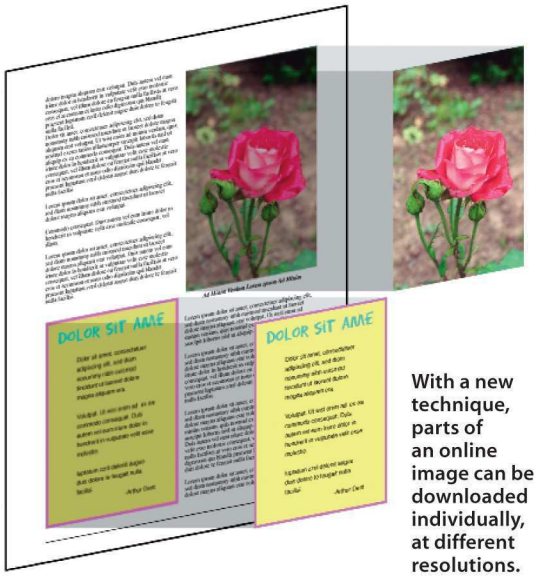
The world's networking company℠

For a network that can, call **1-888-889-0234**

att.com/networking

UNPACKING PIXELS

UNTIL INTERNET CONNECTIONS have infinite bandwidth, big digital files like color images will have to be compressed—which means a loss of detail. But Xerox researcher Robert R. Buckley has come up with a way to compress and transmit different parts of a digital image separately. People viewing the image online could conserve bandwidth by starting with a low-resolution preview but could selectively download portions of the image at higher resolution, showing specific details such as text or a face. Buckley's technique, which is part of the industry's new image compression standard, divides elements such as text and pictures into separate groups, each of which is saved using the best-suited compression method. (Text, for instance, needs to retain its sharp edges, while many photos don't.) The groups can then be downloaded individually, on demand. Xerox plans to license the concept royalty-free to companies developing image-editing software.



With a new technique, parts of an online image can be downloaded individually, at different resolutions.

PORTABLE TRANSLATOR

A device that accurately translates everyday English conversations into Spanish—and vice versa—should be available by the end of the year, if all goes well at Sehda, a startup company in Mountain View, CA. The translator is a one-kilogram notebook computer equipped with a microphone and speakers that will run a phrase recognition program being developed by Sehda. Other machine translators run on powerful computers and cull through enormous databases of previously translated texts to find plausible translations, says Farzad Ehsani, Sehda's founder and CEO. The new device instead uses proprietary methods to detect common phrases, such as "kicked the bucket," then sifts through relatively compact "phrase thesauruses" in both English and Spanish to find paraphrases and idioms that have direct translations. Once Sehda gets the English-Spanish translator right, it plans to build versions of the device for 30 other languages, says Ehsani.

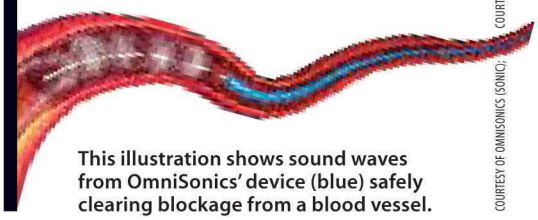
A mock-up portrays a credit card with its own keypad for entering a PIN.

SAFER CREDIT

ON A TRIP TO EUROPE, ED KELLEY FOUND THAT HIS CALLING CARD HAD STOPPED working; thieves had stolen the number and run up huge charges. Frustrated with the lack of security on calling cards and credit cards, Kelley, a group leader for IBM Global Services, sat down with IBM engineer Franco Motika to create a solution. The pair designed a card with a novel feature: a tiny keypad. When the owner first receives the card, he or she must choose and input a PIN that is "burned" into the card's circuitry—making it much more secure than a PIN stored in computer memory. To use the card, the holder enters the PIN on the card itself; this causes a "smart card" chip to generate a unique transaction number good for only one time. This number would be sent to the credit card company, where a computer would compare it to the output of an algorithm specific to that card. Only if the two matched would the transaction be approved. "With this card, somebody could have your credit card number, and it would do them absolutely no good whatsoever," Kelley says.

SONIC CURE

A BLOCKED CORONARY ARTERY CAN LEAD to a fatal heart attack, and few treatment options exist. Surgeons can thread a tiny, laser-tipped wire through the artery to peck away at the clot, but if that doesn't work, they may need to perform open-heart surgery, as they do with 360,000 patients a year. Wilmington, MA-based OmniSonics has an alternative: a wire about the width of the thinnest violin string that emits sound waves. Instead of focusing its energy only straight ahead, as lasers do, the wire produces acoustic energy that radiates outward 360 degrees along its entire length, dissolving the clot and other material built up in the artery but leaving the vessel itself unharmed. The company intends to begin testing on cardiac patients before the end of the year and hopes for U.S. Food and Drug Administration approval by late fall.



This illustration shows sound waves from OmniSonics' device (blue) safely clearing blockage from a blood vessel.

COURTESY OF OMNISONICS (SONIC); COURTESY OF IBM (CREDIT); COURTESY OF XEROX (PIXELS)

COMPANIES THAT WERE JUST IDEAS YESTERDAY RUN SAP.

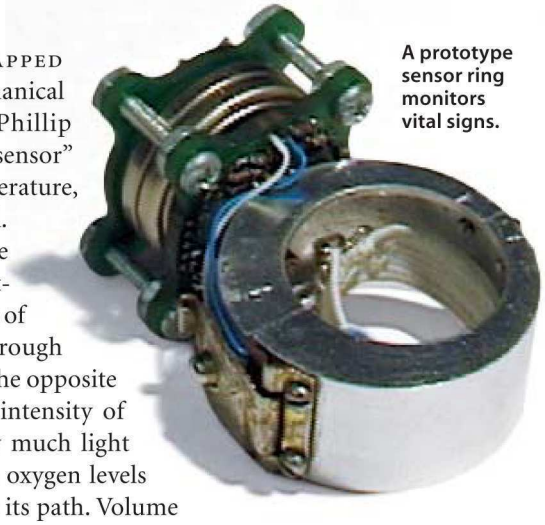
What if you're onto something big, but aren't big yet? Start with SAP® solutions for small and midsize companies. Solutions designed to fit any size business – and any size budget. And because they're built with expansion in mind, they won't just help you grow, they will grow with you. Visit sap.com/ideas or call 800 880 1727, because we have a few big ideas of our own.

Modified silk could help replace torn ligaments.

SILKY KNEE

TEARING THE ANTERIOR CRUCIATE LIGAMENT THAT TRAVERSES THE KNEE joint is one of the most common sports injuries. The ligament doesn't heal by itself, and most people who damage it must undergo reconstructive surgery and six months of rehabilitation. To decrease both the pain and the duration of the recovery, Tissue Regeneration, a Medford, MA-based startup, is creating a replacement ligament based on technology developed at Tufts University. To make the replacement, which also helps the body form new ligament tissue, the company modifies the structure of natural silk. The modifications allow cells in the knee to infiltrate and adhere to the material, and they encourage the growth of new tissue. The material has also been treated so that the silk scaffold slowly degrades, gradually transferring weight-bearing responsibilities to the newly formed natural ligament. The material could also be used in the shoulder, elbow, and wrist. The company hopes to start human trials in 2006 and have the silk-based device on the market by 2008.

MEDICAL MOOD RING



A prototype sensor ring monitors vital signs.

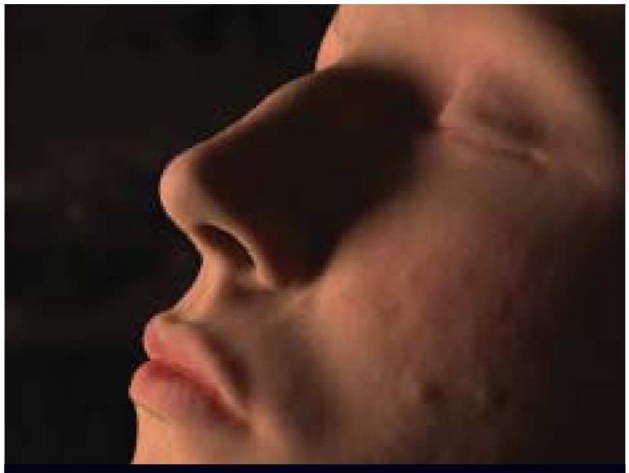
WANT TO HAVE DOCTORS WRAPPED around your finger? MIT mechanical engineers Harry Asada and Phillip Shaltis have developed a "ring sensor" that monitors the wearer's temperature, heart rate, and blood oxygen level. About the size of a class ring, the device is equipped with two light-emitting diodes that beam pulses of red and near infrared light through the user's finger. A detector on the opposite side of the ring measures the intensity of the transmitted light. Just how much light passes through depends on the oxygen levels and the volume of the blood in its path. Volume changes over the course of a heartbeat and can indicate small changes in heart rate. The battery-powered ring contains a wireless link that can transmit vital signs to a cell phone or computer, allowing a caregiver to determine remotely whether a patient needs assistance. The ring could be used in emergency rooms to monitor patients waiting for treatment, in homes to watch patients after heart surgery, and even in cars to check drivers' fatigue levels. The researchers have finished a round of clinical tests and are working with companies to commercialize the device within five years.

MICRO TRACKER

Tiny radio frequency identification (RFID) chips can enable the tracking of everything from pets to batches of razor blades. But their need for antennas to transmit data has held up efforts to shrink them. Now Hitachi has embedded an internal antenna in an RFID chip the size of a fleck of ground pepper using standard semiconductor manufacturing techniques. Special readers provide power to activate the chips and can scan identification numbers from a distance of about one millimeter. Because of the short communication distance, the new chips are not suited for product tracking, but they could be used to authenticate documents such as bank notes, passports, gift certificates, and securities. Hitachi is seeking customers before starting commercial production of the chips, but once a market is found, the chips could be in use within a year.

SOFTER VIRTUAL SKIN

COMPUTER-GENERATED HUMAN FACES USUALLY LOOK PLASTIC and unconvincing on the silver screen; one of the biggest problems is getting simulated light to bounce off the skin just right. Now computer scientists Henrik Wann Jensen of the University of California, San Diego, and Pat Hanrahan of Stanford University have written software that renders virtual skin in a more realistic way. A graphic artist defines the shape and color of the face, the lighting conditions, and the translucency of the skin; the software then uses physics to calculate how light is absorbed and scattered beneath the surface of the simulated skin. That gives the skin a softer, more diffuse, and more natural look than previous computer models did. What's more, the technique requires no more time to render each frame of animation than existing methods, thanks to mathematical shortcuts. Studios and effects companies including Pixar, ILM, and Disney are starting to use the technique, says Jensen.

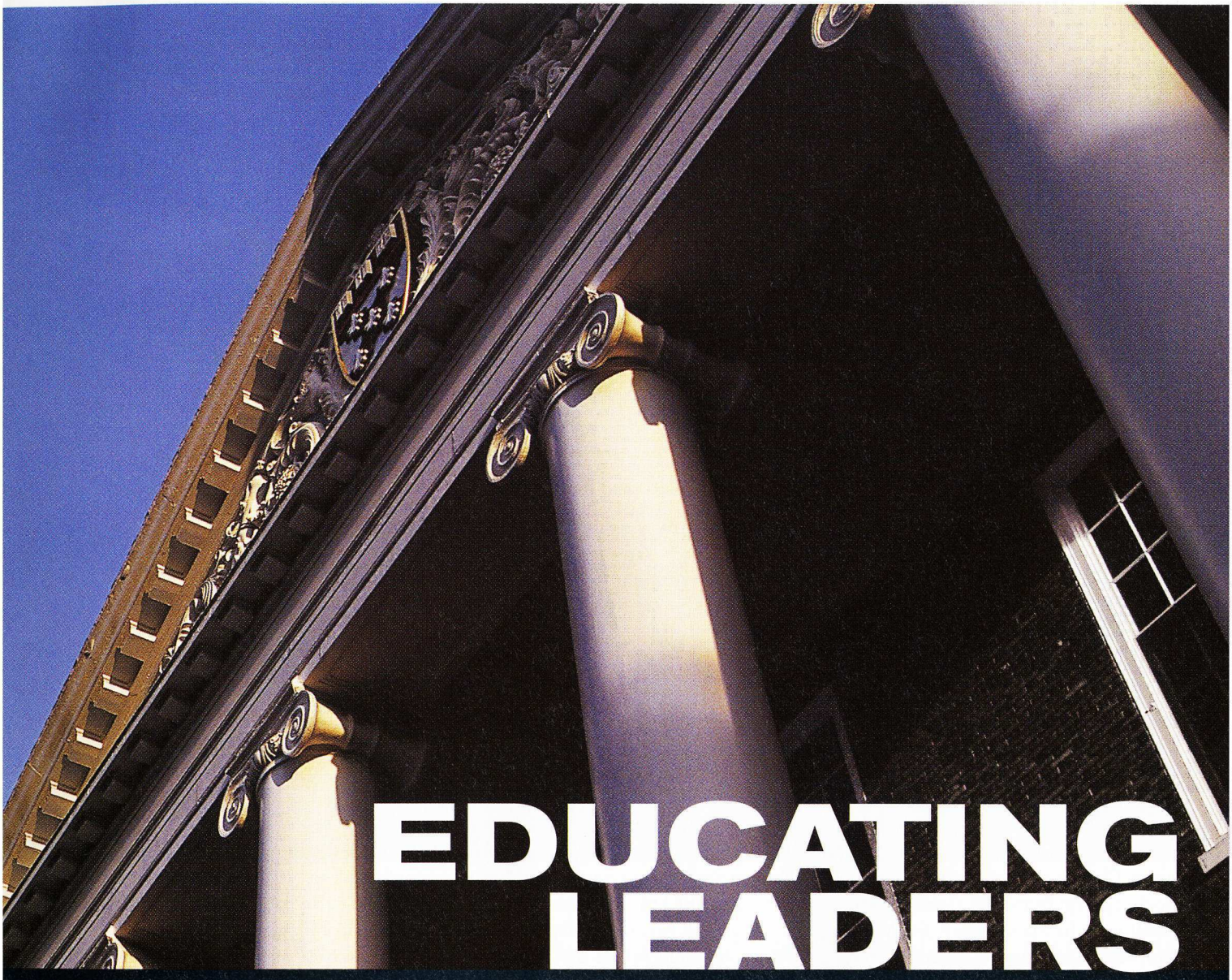


New software renders virtual human skin more realistically.

COURTESY OF HENRIK WANN JENSEN (VIRTUAL SKIN); COURTESY OF HARRY ASADA AND PHILLIP SHALTIS (RING); COURTESY OF REBECCA HORAN, TISSUE REGENERATION (KNEE)

HARVARD | BUSINESS | SCHOOL

EXECUTIVE EDUCATION



EDUCATING LEADERS

WHO MAKE A DIFFERENCE IN THE WORLD

At Harvard Business School, our mission is to educate leaders who make a difference in the world. HBS Executive Education equips the world's most promising individuals with new thinking and actionable learning that quickly translate into real results. Upcoming Executive Education programs include:

ETHICS, FAIRNESS, AND VALUES IN DECISION MAKING	JUNE 13-18, 2004
LEADING CHANGE AND ORGANIZATIONAL RENEWAL: SENIOR TEAMS LINKING STRATEGY TO ACTION	JUNE 13-18, 2004
MARKETING INNOVATIVE TECHNOLOGIES	JUNE 23-26, 2004
LEADING PRODUCT DEVELOPMENT	JUNE 28-JULY 2, 2004
DELIVERING INFORMATION SERVICES	JULY 26-31, 2004
BUILDING COMPETITIVE ADVANTAGE THROUGH OPERATIONS	AUGUST 1-6, 2004
PROGRAM FOR MANAGEMENT DEVELOPMENT	SEPTEMBER 19-NOVEMBER 19, 2004

FOR MORE INFORMATION

E-mail: executive_education@hbs.edu

Telephone: 1-800-HBS-5577, ext. 4142
(outside the U.S., dial
+1-617-495-6555, ext. 4142)

Or visit our Web site at:
WWW.EXED.HBS.EDU

Designed *and* Made in China

WALKING THROUGH BEIJING'S TIANANMEN Square, I was approached by a student who invited me to see her art school's exhibition inside China's National Art Museum. I figured, Why not? ■ Though much of the student work was technically accomplished (yes, it was all for sale to tourists), nothing grabbed me. Then I saw a provocative sequence of boldly colored, sharply angular paintings that looked like nothing else. I bought one. By chance, the young artist was there. His English was good, so we talked about his work and ambitions.

Trying to be helpful, I suggested he post his work on the school's Web site so that potential collectors from around the world could get a taste of his talent. The fellow shook his head and stared at me as if I were an idiot. "If I post my pictures on the Internet," he said, "everybody will then see my style and copy it."

That comment reveals everything one needs to know about how aspiring innovators think in cultures where copying is a legal, social, economic, and creative norm. China is a country whose economy doesn't suffer from "not invented here" syndrome. To the contrary, the Middle Kingdom is a plagiarist's paradise. Imitation is not just the sincerest form of flattery; it's China's industrial-development business model.

So you'll find the latest in pirated DVDs hawked by sidewalk peddlers loitering near Beijing's better hotels. Street vendors provide the finest counterfeit brand-name merchandise from all over the world for pennies on the dollar. Indeed, China's burgeoning "gray market"—unauthorized production runs and off-the-books sales of otherwise legitimate quality goods—enjoys seemingly irrepressible growth.

But perversely, its cavalier regard for intellectual property is precisely why the world's most populous nation is destined to become a global innovation juggernaut. This overwhelmingly copycat culture is rapidly developing an infrastructure for innovation that stealthily but sturdily complements its evolving world-class manufacturing infrastructure.

Imitation is not just the sincerest form of flattery; it's China's industrial-development business model.

"We've all become so dependent on Chinese manufacturing that we've lost the ability to threaten lawsuits for loss of business when they get around to going into business against us," Haysun Hahn, a consultant at trend-spotting firm Futuremode, recently told a conference of U.S. outdoor-apparel companies. "Right now, they're making minor changes in the ideas they're ripping off from you. In three years, those changes won't be so minor.... They want to innovate. They may not be ready to launch their own global brands, but some of the manufacturers I've met are ready to redefine yours."

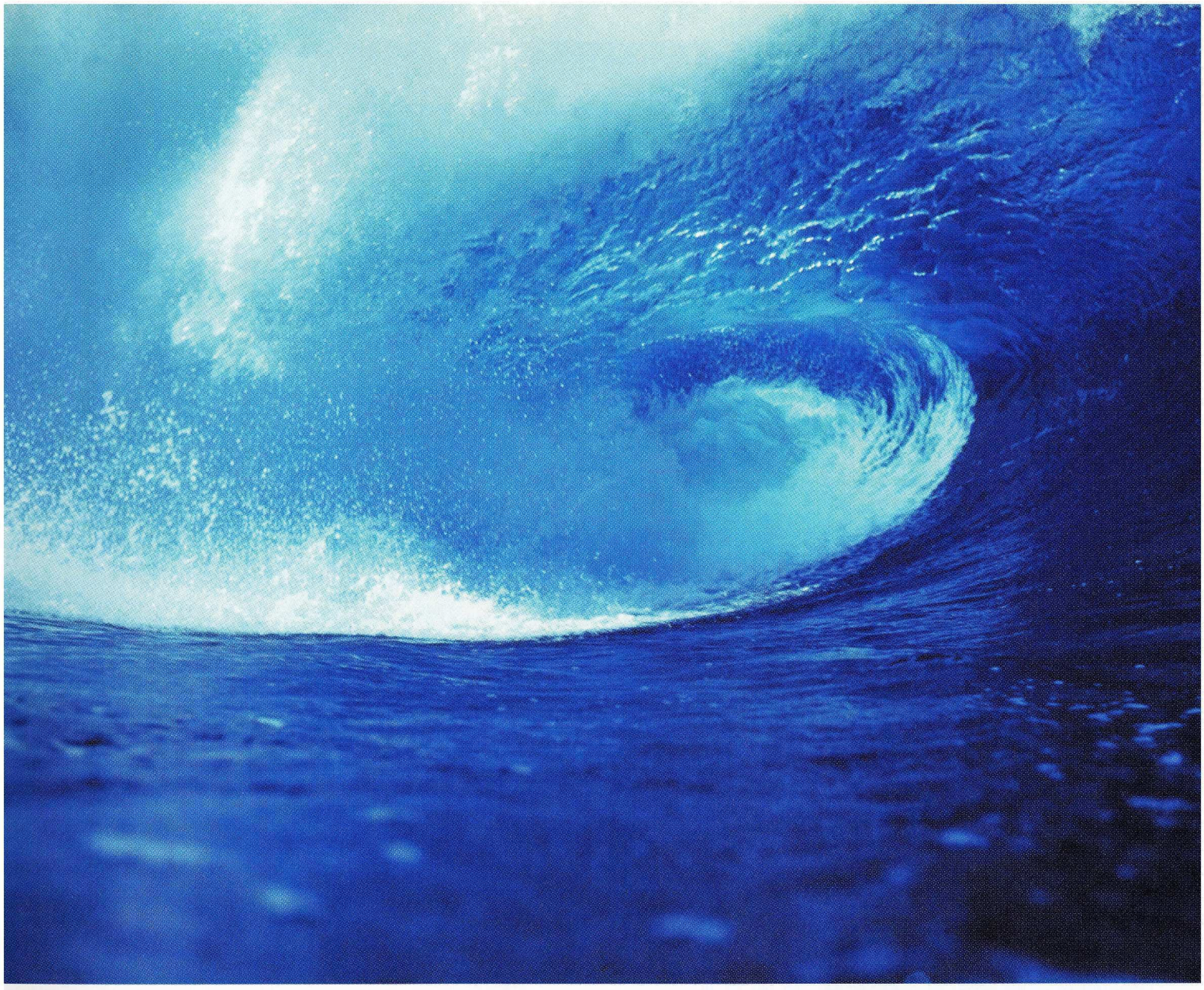
More than any other country in the world, China is about the diffusion of improvements in production processes rather than improvements in end-user technology. Chinese industrialists—and postindustrialists—are on a long march to turn low-cost manufacturing capacity into faster-growth innovation capability. This doesn't mean cutting-edge Chinese companies will mimic Western industrial history and adopt billion-dollar R&D budgets; after all, neither does Dell. Breakthrough inventions may require expensive research, but innovations that make products cheaper and easier to sell anywhere in the world do not. By tapping into the educated but underemployed work force in China's countryside, for example, leading domestic cell-phone manufacturer Ningbo Bird builds nearly as many handsets in China as foreign competitors like Nokia and Motorola—and at lower cost.

China desperately needs advances that generate jobs as well as profitability. Remember, China has a huge demographic Damocletian overhang of unemployed young people. Officials predict that in the next three to five years, Chinese cities and towns will have to provide job opportunities for some 22 to 23 million new workers annually. In other words, unlike Japan and the Asian high-tech "tigers," China has to exploit its economies of scale in ways that will soak up the tidal wave of human capital that threatens to flood its labor marketplace. Can that be done with an industrial base that overwhelmingly defines itself by how well it emulates the innovations of others? I don't think so. Neither does a single Chinese PhD I've spoken with in Beijing, Shanghai, or Singapore.

Innovators and entrepreneurs who think of China as a "build to order" hub of the global supply chain aren't wrong; they're just being overly simplistic. Demographic, industrial, economic, and, yes, technical trends all point to a China whose economic growth is dependent not just on its low-cost appeal but on its accelerating ability to tweak, enhance, and build upon the innovations of others.

Tomorrow's best brands may not be Chinese, but the most intriguing brand extensions—and brand competitors—won't just be "Made in China": they'll be designed in China, as well. How will we know? Because we'll be copying them. TR

Michael Schrage is a consultant, codirector of the MIT Media Lab's e-Markets Initiative, and the author of several books on innovation.



Are you ready for the next big technology wave?

Technology companies around the world count on Dorsey to help them navigate a wide range of business and legal challenges. Dorsey helps technology clients from start-up to IPO and beyond, always protecting key intellectual and technological assets along the way.

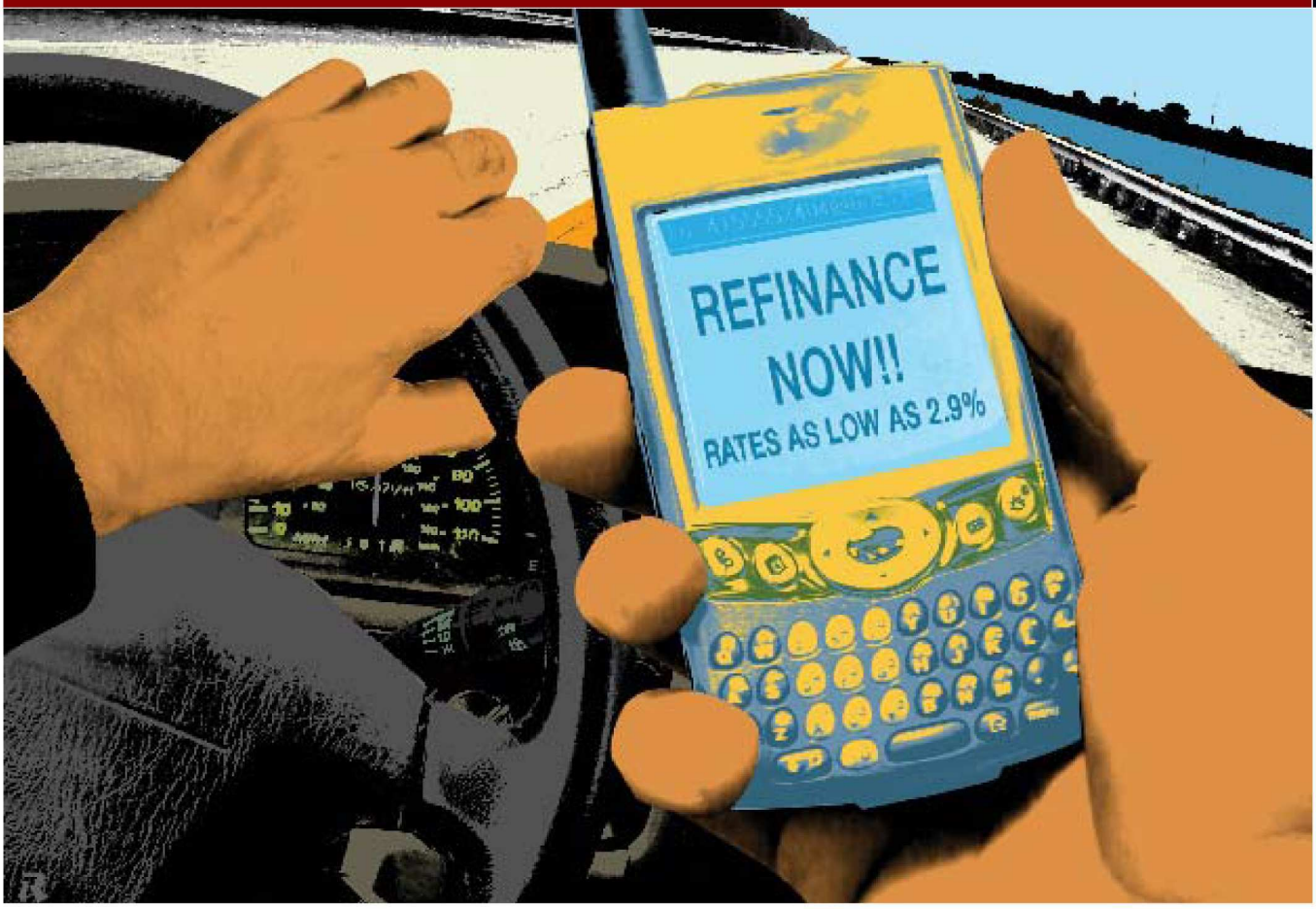
Partner with Dorsey today to ride the technology wave of tomorrow. Visit us online at www.dorsey.com.

USA CANADA EUROPE ASIA

DORSEY

DORSEY & WHITNEY LLP

YOUR SUCCESS IS OUR BUSINESS



Spam to Go

New technologies aim to curb mobile-phone marketing onslaught. **BY WADE ROUSH**

Spam isn't just for your PC anymore. It's rapidly infecting text messaging, too, which means unsolicited ads for refinancing, discount drugs, and pornography can follow you anywhere you take your mobile phone—and even cost you money, if your carrier charges by the message.

The volume of spam text messages originating from the Internet in North America last year actually exceeded that of legitimate messages, according to Wireless Services of Bellevue, WA. Following the lead of Japan, South Korea, and the European Union, California has passed a law aimed at slowing such messages, and in December the U.S. Congress, as part of the CAN-SPAM Act of 2003, directed the Federal Communications Commission to come up with rules protecting cell-phone users nationwide from unsolicited text messages. But wireless companies and software vendors, worried that mobile spam will deter cell-phone users from subscribing to next-generation data services, aren't waiting for new regulations before enacting their own measures to stem the tide. Otherwise, the value of these services will be "completely obliterated," says Jim Manis, president of the Mobile Marketing Association, a trade group focused on the medium.

In November, Wireless Services—one of three companies that handle the text messages sent between the networks of U.S. wireless carriers like Verizon Wireless and SprintPCS—rolled out software that builds on some of the most popular techniques for blocking e-mail spam. "We were getting pressed by our customers to do something," says Eric Lofdahl, the company's director of product management.

The technology starts with Bayesian filtering, which spots spam based on its resemblance to messages in a large database of previously identified spam. But it

JOHN RITTER

adds a quarantine system. "Maybe there's a URL that the spammer wants somebody to hit," Lofdahl explains. "We'll count how many messages transit our system that have that URL in them over a certain time frame, and if that number exceeds a threshold, we will start diverting those messages into a quarantine area for somebody to look at." When legitimate messages get quarantined, the company's spam spotters usually release them within minutes, Lofdahl says.

Wireless companies aren't waiting for new regulations before enacting their own measures to stop mobile spam.

The company is working to make its spam filters customizable, so that cell-phone owners can decide which messages to accept rather than depend on the carriers' standards. Right now, says Lofdahl, "If you really are in the market for debt refinancing, you probably aren't going to get many of the messages you want sent to your cell phone about that." The company's improved software, being implemented this year, would let you unblock messages containing certain keywords, such as "debt" or "mortgage."

Giving wireless subscribers more control over their text message in-boxes is also the goal of software under development at Lucent Technologies' Bell Labs in Murray Hill, NJ. Lucent's system looks forward to the near future, when so-called location-aware applications could make mobile spam all the more insidious *(see "WhereWare," TR September 2003)*. Federal requirements that most cell phones be capable of reporting their geographic location to 911 emergency systems by 2005 have inspired wireless carriers and marketers to dream up non-emergency uses for their newly gained ability to track phones—say, sending you a coffee ad or coupon when you get within a certain range of a café.

Lucent's prototype lets carriers create online menus with which customers can specify things like which kinds of businesses they'd like to receive messages from, at what times of the day or week, and within what geographical radius. "If the consumer can block a merchant from viewing his location information, the merchant has no idea they're passing by," explains Rick Hull, Bell Labs' director of network data and services research. Over the coming year, the software will be folded into existing software that handles data moving between the Internet and telecommunications networks.

Meanwhile, even more-exotic spam is starting to show up. In South Korea, Japan, Britain, and parts of the United States, next-generation cellular networks allow high-bandwidth data transfer, so messages can include not just text but also photos and animations.

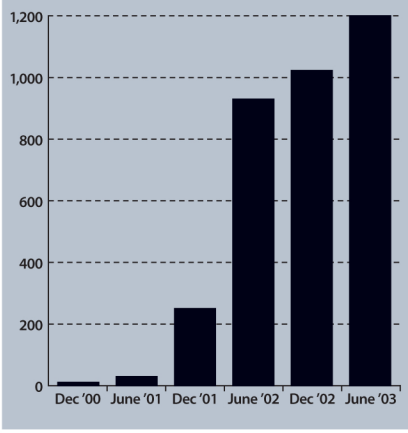
With multimedia spam already a problem, wireless providers are trying "opt-in" requirements similar to those already in use in Europe to keep such elaborate junk ads under control. In the United Kingdom and other countries, wireless carriers use a system of "common short codes," five-digit numbers that consumers find on billboards or magazine ads and type into their phones to receive text-based promotions. Last October, U.S. wireless carriers agreed to a similar system.

Of course, clever spammers will keep finding ways to sneak some messages past industry controls. "It's like those old *Mad* magazine 'Spy versus Spy' cartoons: spammers come up with something, and we have to come up with something to counteract it," Lofdahl says.

And this means the 150 million cellular subscribers in the United States—the majority of whom own phones capable of two-way text messaging—have little chance of entirely avoiding getting spammed. TR

MESSAGING THROTTLES UP

Total number of text messages sent in the United States for the given months, in millions



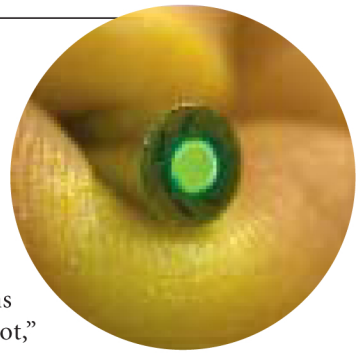
SOURCE: CELLULAR TELECOMMUNICATIONS AND INTERNET ASSOCIATION (MESSAGING THROTTLES UP)

STOPPING MOBILE SPAM IN ITS TRACKS

COMPANY	TECHNOLOGY/STATUS
Brightmail San Francisco, CA	Software that uses thousands of decoy accounts to detect text message spam and blocks messages from suspect addresses; being tested by European wireless providers
Lucent Technologies' Bell Labs Murray Hill, NJ	System that blocks unsolicited text messages based on location, time, and other factors; will be added to cellular-networking software this year
Openwave Redwood City, CA	Software that blocks messages from cellular networks if they arrive in high volume or from untrusted sources; launched in the United States in February 2004
Telcotec Dublin, Ireland	Software for cellular networks that analyzes images in multimedia messages and offers subscribers the option to block adult content; launched in May 2003
Wireless Services Bellevue, WA	Spam-blocking software for cellular networks based largely on established techniques for e-mail spam detection; launched in November 2003

DIAGNOSTICS

Shining Light on Cancer Diagnoses



An optical probe could diagnose cervical cancer.

Traditional screening for cervical cancer—a Pap smear followed by microscopic examination of the cervix—often gives false positives that force needless, painful, and costly biopsies. A new optical diagnostic device now being tested in large human trials could give more precise answers cheaply. And it could reach patients in two to three years.

The new technology is a pencil-sized probe that shines ultraviolet and visible light onto the cervix. Precancerous cells contain more mitochondria—the power plants of cells—which fluoresce when light of those wavelengths strikes them; so an increase in fluorescence means more precancerous cells. In a study of more than 100 women last year, researchers at the University of Texas at Austin and the M. D. Anderson Cancer Center in Houston, TX, found the method provided 50 percent fewer false-positive readings than standard methods. Now, two trials involving 1,800 women in Texas and Canada are under way, and the technology could be ready for the U.S. Food and Drug Administration's approval process next year, says Michele Follen, an oncologist at M. D. Anderson. "Physicians could screen, diagnose, and make decisions about treatment all in one shot," says Rebecca Richards-Kortum, a biomedical engineer at the University of Texas and one of the probe's developers. That would be particularly welcome in developing countries, where most of the world's 300,000 annual cervical-cancer deaths occur, and where today's testing methods are unavailable or beyond the means of most women. In the U.S., Follen estimates, widespread adoption could save more than $600 million a year in health-care costs.

DIAGNOSTIC WAVELENGTHS

RESEARCHER	TECHNOLOGY/STATUS
Michael Feld, MIT	Light probe for oral-, cervical-, and esophageal-cancer screening; now in human testing
Nimmi Ramanujam, University of Wisconsin-Madison	Optical fiber threaded through biopsy needle to guide breast biopsy; in human trials
Rebecca Richards-Kortum, University of Texas at Austin	Ultraviolet- and visible-light-emitting device for cervical-cancer screening; regulatory filing could come as early as next year
Bruce Tromberg, University of California, Irvine	Handheld infrared device for breast cancer screening; could enter large-scale human testing in three years

Other groups are using infrared light to check for breast cancer. At some wavelengths, infrared light can penetrate several centimeters into the body and is sensitive to changes in blood oxygen content and blood volume, which correlate with tumor growth. "In a few years, radiologists are going to be able to press a button and get optical information to complement mammography," says Bruce Tromberg, a biomedical engineer developing an optical breast-cancer screening test at the University of California, Irvine. Using light also avoids the need for radiation, says Daniel Sullivan, head of the cancer imaging program at the National Cancer Institute in Bethesda, MD. He cautions that optical imaging won't replace existing methods but could complement them to improve accuracy and reduce needless biopsies. **Corie Lok**

STARTUPS

Gloom Lifts for Venture Capital

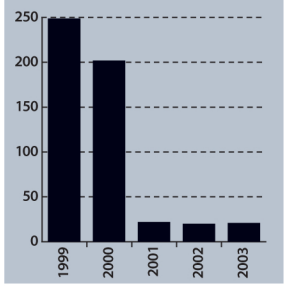
The past two years have been brutal for emerging technology companies seeking venture capital investments. But that's changing. Following a burst of initial public offerings late last year, venture capitalists are already loosening up their purse strings for the next batch of startups.

In the fourth quarter of 2003, venture capital firms raised $5.2 billion, almost half of what they raised in all of 2003. During the same period in 2002, they raised just $2.1 billion. And there are some clear indications about where venture investors are looking to spend their money. "There still seems to be a tremendous amount of interest in the wireless sector, in enterprise security applications and consumer electronics products," says Kenneth Lawler, a general partner at Battery Ventures in San Mateo, CA.

The renewed interest in venture capital is partially fueled by signs that opportunities for lucrative public offerings are returning. Although just 29 venture-backed companies went public in all of 2003—a paltry number by historical standards—17 of those were in the fourth quarter and raised $1.05 billion, an average of $61.7 million per offering. The largest contribution to these fourth-quarter IPOs came from the medical and health-care sector, with five companies, followed by consumer products and services with three. Still, experts are cautious. "The [initial public offering] market is still very challenging. It's not as if any kind of floodgate has opened here," says John Gabbert, vice president of research at VentureOne, a San Francisco-based venture research firm.

VENTURE PAYDAYS

Number of U.S. venture-backed IPOs

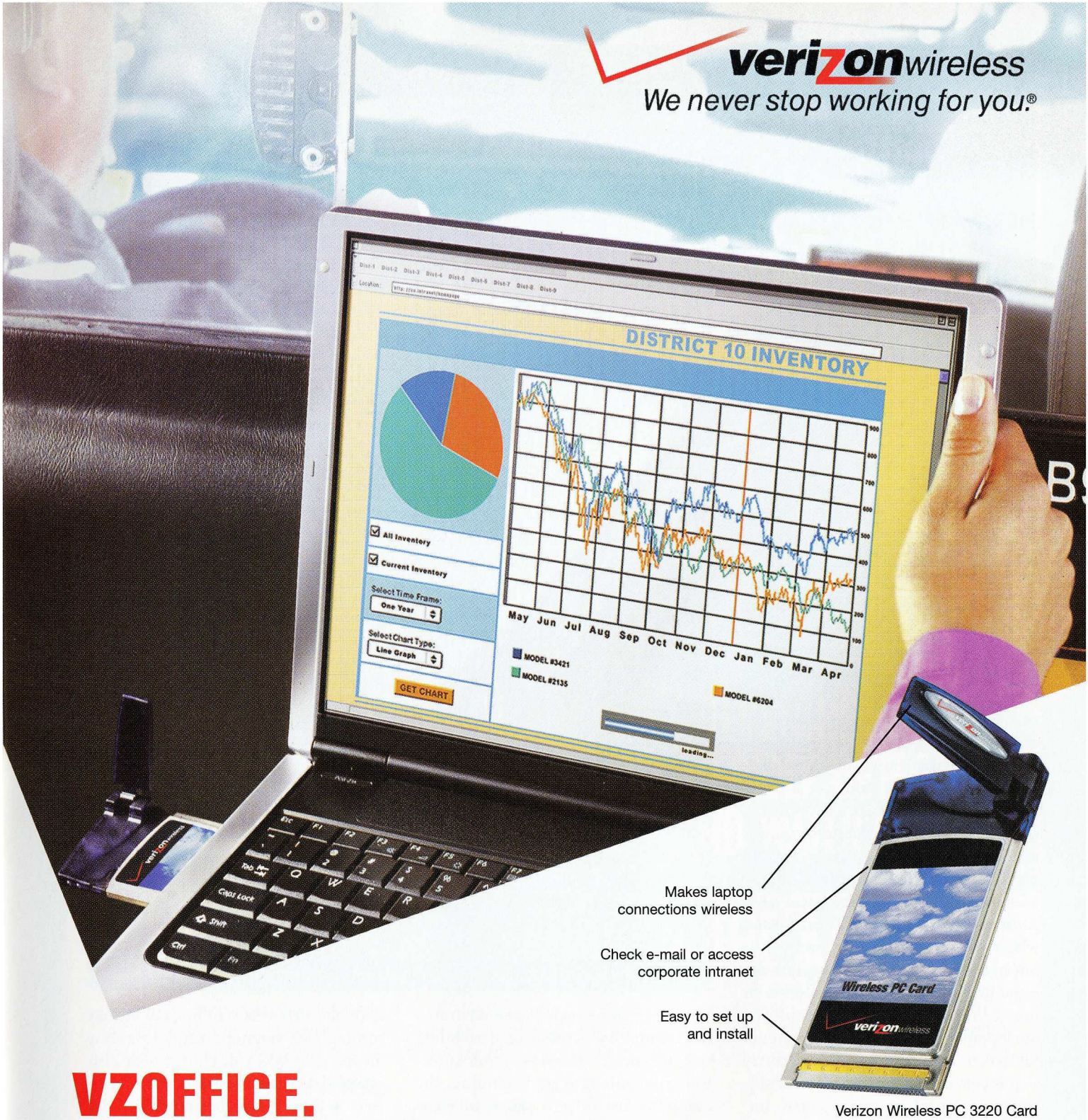


Whether the momentum in the venture market will hold up is anyone's guess. But at least some rays of hope are penetrating the gloom. **David Talbot**

SOURCE: THOMSON VENTURE ECONOMICS AND NATIONAL VENTURE CAPITAL ASSOCIATION (PAYDAYS); PHOTO: COURTESY OF BOB KNIGHT, UNIVERSITY OF TEXAS AT AUSTIN (CANCER)

verizon wireless

We never stop working for you.®



Verizon Wireless PC 3220 Card

VZOFFICE.

For Remote Access On The Road, Take Our Business Card.

Remote Access from **VZ**office℠ keeps your employees productive when they're on the road. Because with our wireless PC card in their laptop, they can enjoy easy, convenient access to the Internet, corporate intranet, e-mails, databases, files and applications. So they can take care of business anytime—without having to seek out a landline wire, jack or ISP again. One more reason why, for all your company's wireless needs, we mean business.

Contact our business representatives at 1.866.899.2862 or log on to verizonwireless.com.

MEMORY

Matsushita's Gamble

Japanese electronics giant bets future on radical new chip

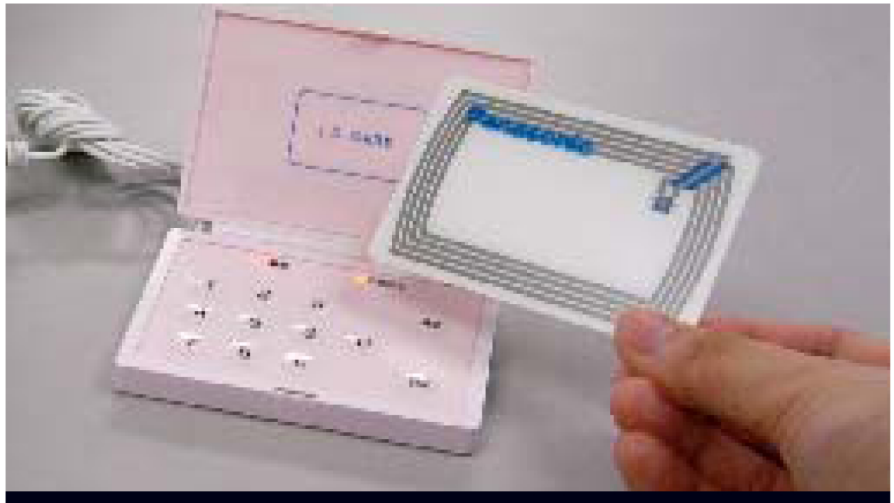
SUSUMU KOIKE IS HOLDING court over lunch at the Kyoto, Japan, offices of Matsushita Semiconductor, the company he heads. Matsushita Semiconductor is a subsidiary of $62-billion-a-year Matsushita Electric Industrial, the world's second-largest consumer electronics manufacturer (behind Sony), whose product lines include Panasonic, Technics, and Quasar. A pugnacious 58-year-old engineer, Koike describes one of Matsushita's latest achievements this way: "Reconfigurable FeRAM is our Mount Everest."

Koike's metaphor refers to the company's broad goals for chips that use ferroelectric memory, a new technology that could help make a vast array of consumer electronics—from TVs to handheld computers to cell phones—more versatile and cheaper and, in some cases, faster and smaller. It should ultimately mean more multifunctional digital products, for less money.

To understand Koike's enthusiasm, consider the cell phone. Yesterday, it was just a phone. Today, it has a built-in digital camera. Tomorrow, it might have a Global Positioning System–based navigator, an MP3 player, an ID card—and who knows what else. The problem is one of squeezing extra features into the same gadget without raising costs or increasing power consumption. The most popular strategy for semiconductor makers is to cram as much circuitry as possible onto the same piece of silicon, an approach known as system-on-chip. To switch from one function to another, the chips need to be programmable or, in industry jargon, "reconfigurable." Software effectively reprograms the chip's circuits to do different jobs.

That approach requires lots of memory, however, to store the software, and that's where Koike believes his company has climbed ahead. Matsushita didn't invent ferroelectric memory, but it is the first to mass-produce it on a system chip. Ferroelectric memory, like today's standard flash memory, retains data even when the power shuts down, but it's far easier to fabricate. It also stores data much faster than flash, with much lower power consumption—a key consideration for battery-driven portable devices.

Matsushita's new chips debuted commercially in December 2003, inside smart cards used as season tickets by Japan Rail commuters in Osaka. The chips are much smaller than conventional equivalents, which means they are cheaper to manufacture, and they run on only a fraction of the power.



A Matsushita prototype smart card, shown with card reader, includes a new type of memory chip.

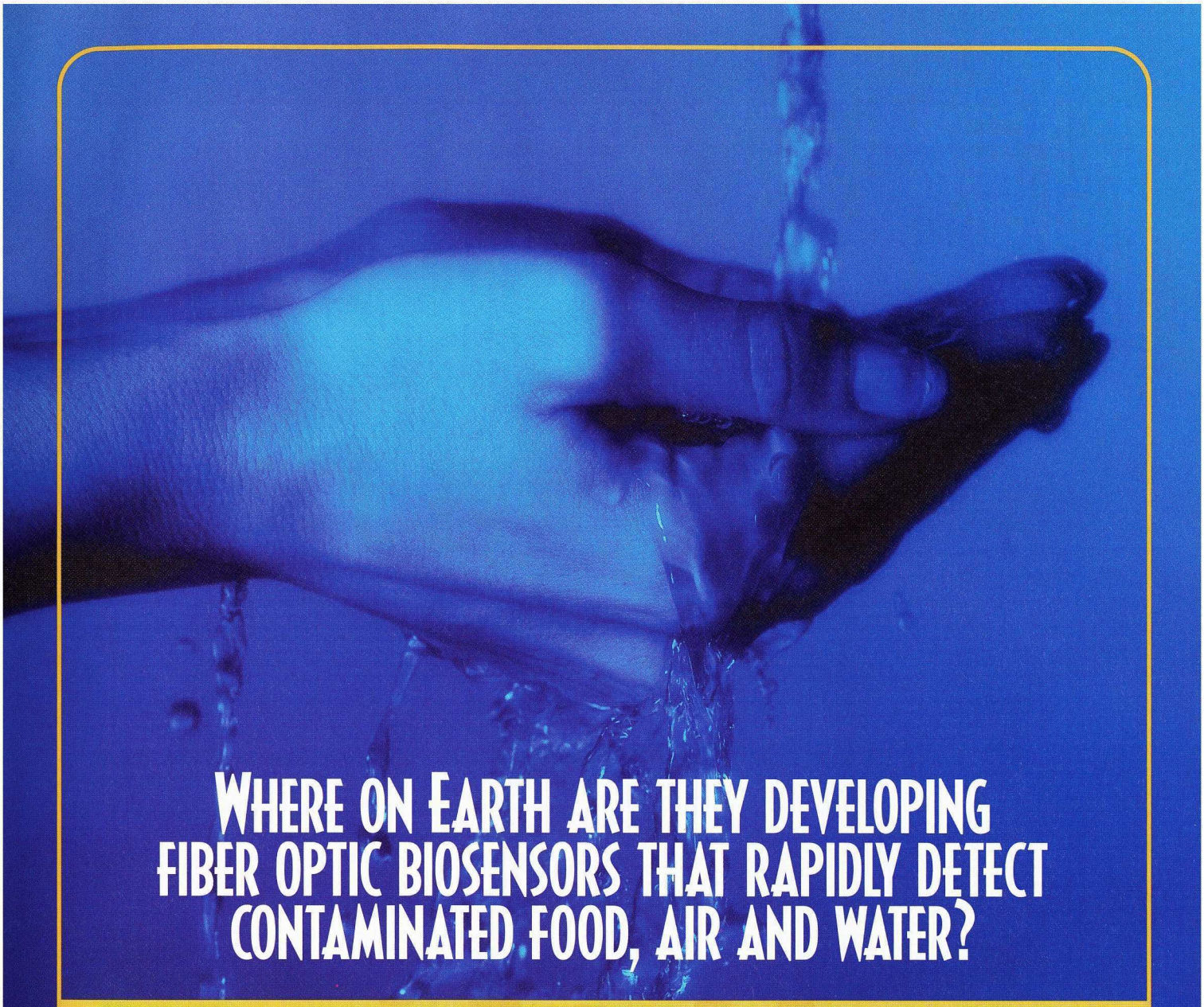
These chips merely demonstrated the technology's commercial viability; rail cards don't need to be reconfigured. But from this modest beginning, the company intends to move forward aggressively. One early application where ferroelectric memory could have a large impact, Koike says, is in chips for cell phones that could be used around the world. Today, cellular-service providers in each country have different protocols, which means they require different types of phones. "It would be quicker to download the appropriate protocol into reconfigurable memory" and just use one phone, says Koike. But that's just one idea; he predicts that the global market for system-on-chip with embedded ferroelectric memory will grow to $5 billion by 2010.

That's a plausible projection, says Carlos Araujo, a professor of electrical engineering at the University of Colorado at Colorado Springs and chairman of Symetrix, the company that pioneered the type of memory the Japanese firm uses. "This is no longer like, 'Gee, we've got this new technology, and we're trying to find something to do with it,'" he says. "This is more like, 'We have products out, and we're realigning all of Matsushita around this technology, and all our products from cell phones to digital TVs will have it.'"

Of course, Matsushita's rivals are working on their own next-generation memory technologies; this year, for example, Motorola is rolling out its first commercial magnetic random-access memory, or MRAM, chip, which also retains data when the power shuts down *(see "A Chip Worth Remembering," TR March 2004)*.

But whereas Motorola's chip is too expensive for all but high-end applications, Matsushita's is cheap enough for use in commuter-rail cards. Indeed, with production volumes running at millions of devices per month, Matsushita has proved that ferroelectric memory can be mass-produced. It has scaled the first peak. Whether other rivals also advance on the summit remains to be seen. **Bob Johnstone**

COURTESY OF MATSUSHITA ELECTRIC INDUSTRIAL



WHERE ON EARTH ARE THEY DEVELOPING FIBER OPTIC BIOSENSORS THAT RAPIDLY DETECT CONTAMINATED FOOD, AIR AND WATER?

FLORIDA. INNOVATION HUB OF THE AMERICAS.®

Florida researchers are developing a fiber optic device that quickly and accurately detects pathogenic organisms and microbial toxins in food, water, air and on surfaces. The portable unit allows anyone – with or without a scientific background – to test samples and see results within minutes. Visit **eflorida.com/biosensor** to discover why innovative businesses like yours belong in an innovative state like Florida.

Southwest Florida
Consider: 600+ technology companies, a highly-skilled workforce, a bustling economy and low business costs, all wrapped around an enviable lifestyle. **www.esouthwestflorida.com**

SOUTHWEST FLORIDA
BUSINESS IN PARADISE

Tampa Bay
Home to Florida's only National Cancer Institute - Moffitt Cancer Center and Research Institute, a thriving cluster of medical device and pharmaceutical manufacturing and the University of South Florida's new biotechnology and life sciences research center.
www.TampaBay.us

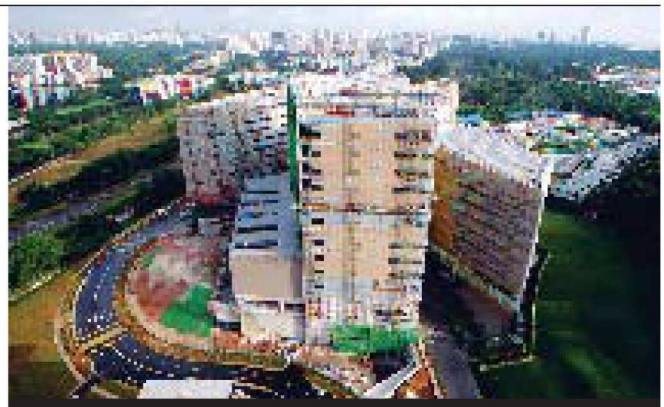
TAMPA BAY
The Climate is Right!
FOR BUSINESS

eflorida℠
eflorida.com

eflorida.com/biosensor • 407.316.4600

NANOTECHNOLOGY

Singapore Center Sets Ambitious Goals


Singapore's Biopolis center will include a nanotech institute.

EFFORTS TO COMMERCIALIZE NANOTECHNOLOGY ARE gaining momentum around the world. But nowhere are those efforts more intense than in the high-tech centers of Asia. In the most recent illustration of this trend, Singapore's Institute of Bioengineering and Nanotechnology is rapidly emerging as a world leader in nano-based biosensors and diagnostic devices. Already home to more than 100 researchers, the nanotech institute, which is part of Singapore's new Biopolis biomedical research center, has applied for a dozen patents over the last year and plans to translate its most advanced research projects into commercial products in the next few years.

The institute reflects heavy nanotech investments by several governments in Asia—chiefly China, Japan, South Korea, Taiwan, and Singapore—that aim to produce everything from extremely sensitive diagnostics to superfast computers. In particular, Japan, South Korea, and China "will be world nanotech leaders in the next few years," says David Tomanek, a nanotech expert at Michigan State University who maintains a research group at Tokyo's Research Organization for Information Science and Technology. "In some areas, you could say they're leading now."

One of the nearer-term efforts at the Singapore center is a new blood-glucose sensor that allows people with diabetes to draw one-tenth the amount of blood required by conventional home systems and get readings in five seconds. The device uses a thin membrane dotted with tiny holes and laden with sensors; the holes control the flow of blood so the sensors have better access to the glucose molecules contained in it. The Singapore center says it is in discussions with an unnamed company that might commercialize the device in two years.

Other devices in the works include ultrasensitive sensors for detecting the molecular and genetic signals of breast cancer and SARS and strong, durable orthopedic implants. "Nanotech allows you to tailor biomaterials and devices in an unprecedented manner. You can do better than nature," says Jackie Ying, the executive director of the institute, currently on leave as an MIT professor of chemical engineering. And when it comes to improving on nature, the Asian nanotech centers hope to do better than their counterparts around the world. **Gregory T. Huang**

SAMPLING OF NANOTECH LEADERS IN ASIA

ORGANIZATION	TECHNOLOGIES
Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, Changchun, China	Fast, stable sensors for biomolecule analysis and diagnostics
Institute of Bioengineering and Nanotechnology, Singapore	Biosensors, medical implants, and sensitive biochips for diagnostics
Korea Advanced Institute of Science and Technology, Daejeon, South Korea	Sensors and chips for detecting toxins
NEC, Tokyo, Japan	Carbon-nanohorn-based fuel cells
Samsung Advanced Institute of Technology, Giheung, South Korea	Carbon-nanotube-based flat-panel displays

TELEMATICS

Dashboard Jukebox

The in-dash CD player just might be poised to go the way of the eight-track tape deck. Coming soon: an in-dash computer that can accept wireless downloads of songs—and even movies—from your home or office. You would drag files to an icon on your PC's desktop representing your vehicle's entertainment center, and a wireless Internet connection using the popular Wi-Fi standard would beam the data to your parked vehicle.

Moving tunes to cars "is the killer app" for wireless vehicle technologies, says Bob Schumacher, head of the Kokomo, IN-based wireless business unit of Delphi, a major auto supplier. "It'll be like having a jukebox in your car." Indeed, Phil Magney, principal analyst for the Telematics Research Group in Minnetonka, MN, says drivers will want Wi-Fi in their cars for the same reasons "they want broadband on their computer": to quickly get video and music.

Already, another wireless technology, Bluetooth, is showing up in optional equipment for some cars, enabling hands-free cell-phone chatting by connecting the phone to the car's audio system. Unlike Bluetooth, Wi-Fi has high bandwidth and a range of more than 100 meters—enough to beam tunes to your wheels. Some car parts suppliers have started making Wi-Fi-enabled sound systems. Delphi says it is working with at least two unnamed automakers to put Wi-Fi into cars as original equipment, which could hit showrooms by 2007. And once Wi-Fi is on board, drivers could also check their e-mail, download news or traffic reports, or even control Internet-linked home heating systems when parked near Wi-Fi nodes. But for starters, it could mean the end of CD cases stuck between the seats. **Corie Lok**

COURTESY OF JTC CORPORATION

Your Next Mission: Driving IT Initiatives That Demonstrate Business Value

Find out more at:

GigaWorld IT Forum:

Creating Business Value With IT

May 17–20, 2004 • JW Marriott Orlando Grande Lakes • Orlando, Florida

FORRESTER®

Aligning IT with business strategy remains key to your organization's survival and success. The business economy is recovering, but new issues, new challenges, and new choices emerge every day.

How do you keep up with changes and advances in technology? Are you under pressure to deliver more value, more profit? Are you faced with increased expectations and decreased funding? How do you get and stay on track? And where do you start?

The challenges are daunting. Fortunately, your first step is clear. Attend GigaWorld IT Forum 2004.

Now in its eighth year, GigaWorld IT Forum has set the standard in delivering hard-hitting, relevant research and peer-to-peer networking opportunities. A widely focused Event, GigaWorld's agenda spans the course of four days, features more than 100 sessions, and covers all of the major issues at the forefront of technology today.

It's the must-attend Event for IT and business executives charged with choosing and implementing technologies that gain — and maintain — competitive edge.

From IT strategy to IT portfolio management, from application development to outsourcing, from content management to user experience, GigaWorld IT Forum delivers high-value content on up-to-the-minute issues addressing the full range of technology and IT management challenges.

Attend this Forum and find out how to:

- Select the right technologies for sustainable competitive advantage.
- Realize full value from your IT investments.
- Manage IT through change while minimizing risk.
- Better serve your business from strategy to solution.
- Build and manage the distributed enterprise.

GigaWorld IT Forum
May 17–20, 2004

Register TODAY!

Call +1 888/343-6786 or visit www.forresterevents.com/gigaworld2004.
Please mention VIP code F04GWA4 when you register.


Help us find the next
TECHNOLOGY
SUPERSTARS
TECHNOLOGY
REVIEW

TR100

2004 AWARDS

CALL FOR NOMINATIONS

Who are today's top young innovators in biotech, computing, nanotech, and other emerging technologies? What will the world look like 5, 10, 30 years down the road? Who are the leading young innovators already laying the foundation for this technological future? Help us find them and tell their stories.

Nominations are now open for the 2004 edition of the TR100, *Technology Review*'s list of 100 young people whose contributions to emerging technologies are poised to profoundly influence our world. We're seeking the best young innovators in such fields as biotechnology, computing, energy, medicine, nanotechnology, telecommunications, and transportation.

Nominees should not turn 35 before October 1, 2004, and their work should exemplify the spirit of innovation. *Technology Review* will showcase all 100 in a special October 2004 issue and recognize them at a gala awards celebration at our Emerging Technologies Conference, September 29-30, 2004.

The deadline for nominations is March 31, 2004.

To Nominate Visit:

www.technologyreview.com/tr100/nomination

Technology's Elder Boom

I RECENTLY HAD A BIRTHDAY. IT HAPPENS EVERY year: I get older. And I'm not the only one. The average age of people in the industrialized countries, China, and India is on the rise. Which means that by 2050—when some projections hold that the world's population will peak at about nine billion, then start declining—there will not only be far more people, but also proportionately more elderly and fewer young people to care for them. Life expectancy is increasing around the globe, too.

But we won't have to wait until 2050 to feel the impact. These trends will significantly affect all industrialized nations within 20 years—and profoundly influence the course of technology development even sooner than that. For starters, medicine in general and biotechnology in particular will get skewed more toward the concerns of the elderly. Research on ways to increase mental alacrity, decrease memory loss, suppress cancers, and treat heart disease will intensify.

From memory drugs to tele-socializing to robotic walkers, technology development will get skewed to the needs of the old.

But information technology, too, will see new application areas. Staying within the medical domain for a moment, demand will rise for wireless sensors embedded within people's bodies and ad hoc wireless networks that provide early warnings about internal medical problems. Such invited bodily invasions will fare a lot better if there are concomitant improvements in privacy and security as personal information gets shuttled around.

The first likely beneficiaries of such technologies are now in their 40s and 50s. Many of them have spent the last twenty years adopting information technology wholesale, which means they will probably continue to adopt new technologies as they grow older. People will be nostalgic for the information content of their youth, and many will want to learn new things. There's a surging tide of content out there to satisfy them; in addition to decades of TV shows—and the growing archive of cable TV documentaries—universities are globalizing their reach by offering courses and materials through the Internet. What's needed are ways to index and search for video, audio, and images that are as simple as the search engines that help us find and understand text documents today. The aging population will provide a big customer base.

This leads us to the more general question of how the economics will work out with so many retirees and so few taxpayers. Technology will continue to be called upon to increase productivity in any way that it can, and to provide part-time work possibilities for the elderly. For instance, elderly people might act as remote quality-control inspectors or security monitors, or even provide high-level remote commands to maintenance or construction robots.

Technology will certainly help alleviate social isolation. People's demand to continue socializing as they grow less able to travel and visit directly will create new markets for tele-visiting, tele-socializing, and tele-role-playing. Graphics, computer vision, and speech understanding are all components of providing friendly and comfortable immersive experiences. (And anyone who can invent a real-world version of *Star Trek*'s "holodeck"—a virtual-reality room that conjures any scene or situation from any time or place—will find plenty of elderly customers.)

The desire of the elderly to stay in their homes longer before entering care facilities will present opportunities for robots to tackle physical tasks. In a number of small installations, robots have acted as orderlies, carrying food trays and shuttling laundry carts about. This reduces labor requirements and frees nursing staff to spend more time with patients. Similarly, one can imagine a robotic shopping cart that follows a person in the supermarket, puts itself in the car, and carries the groceries up the steps at home—or a robotic car that gets the really elderly to the supermarket in the first place.

Ultimately, robots might be used to take on some of the more direct aspects of elder care for the infirm. Robotic walkers might help people get into and out of bed or the shower (note to manufacturers: waterproof your robots) and move around their houses. And we might want robots that can get the dishes to and from the dish-cleaning robots (we already have those: they're called dishwashers). None of these robots is very far beyond what could be demonstrated in the laboratory today for sufficient dollar investments. The question is whether costs will drop and reliability improve in time for the aging baby-boomers.

The bottom line is that as we get older, we are unlikely to return to the "simpler" life of our childhoods, when technology was less pervasive than it is today. Rather, the pressures of demographics and our own predilections are going to lead us to continue to adopt new technologies and new ways of interacting with our machines, and we'll probably be much happier for it.

Rodney Brooks is director of MIT's Computer Science and Artificial Intelligence Laboratory.

Celebrating 15 Years of Ventuve Capital Investing

IBF Conferences Presents

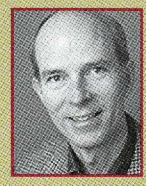
VENTURE CAPITAL INVESTING 2004

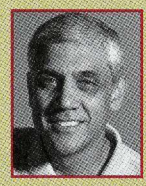
Conference Chairmen:

PETER MORRIS
General Partner
New Enterprise Associates

RICHARD J. HAYES
Senior Investment Officer,
Alternative Investments
CalPERS

Advisory Board Chairman:
GARY MORGENTHALER
General Partner
Morgenthaler Ventures





Q&A Keynote Session With:
VINOD KHOSLA,
General Partner, Kleiner
Perkins Caufield & Byers

THE PREMIER CONFERENCE FOR VENTURE INVESTORS

June 9-11, 2004 • Ritz Carlton Hotel • San Francisco, CA

This annual industry meeting brings together the most active venture capitalists and private equity investors representing over a $ trillion dollars in capital to discuss investing strategies.

ADVISORY BOARD CHAIRMAN:

Gary Morgenthaler
General Partner, Morgenthaler Ventures

ADVISORY BOARD MEMBERS:

Todd Chaffee
Managing Director
Institutional Venture Partners

Richard Kramlich
General Partner, New Enterprise Associates

Sandra A. Ell
Treasurer and Chief Investment Officer
California Institute of Technology

Charles Froland
Managing Director
General Motors- Investment Management

Barry Gonder
General Partner, Grove Street Advisors

Richard J. Hayes
Senior Investment Officer
Alternative Investments, CalPERS

Doug Hamilton
Managing Director, Silicon Valley Bank

Mark Heesen
National Venture Capital Association

Ted Schlein
Managing Director
Kleiner Perkins Caufield & Byers

James Swartz
Founder, General Partner, Accel Partners

Arthur Klausner
General Partner, Domain Associates, LLC

Tracy T. Lefteroff
Global Managing Partner,
Private Equity, PricewaterhouseCoopers LLP

John B. Mumford
Founding Partner, Crosspoint Venture Partners

Vincent M. Occhipinti
Managing Director
Woodside Fund

Robin A. Painter
Partner, Testa, Hurwitz & Thibeault, LLP

Georganne F. Perkins
Private Equity Investment Officer
Stanford Management Company

Jonathan Root
General Partner, US Venture Partners

OVER 75 ACTIVE VENTURE CAPITALISTS AND LIMITED PARTNERS WILL SHARE THEIR STRATEGIES AND PERSPECTIVES ON:

- RETURN OF THE VENTURE MARKET
- FUND-RAISING RENAISSANCE: GUIDELINES FOR STRUCTURING YOUR NEXT FUND
- EXITS & LIQUIDITY: ARE HISTORICAL NORMS OF RATIONAL EXPECTATIONS AND RETURNS ANTICIPATED
- HOW ARE VENTURE FIRMS ENSURING THE NEXT GENERATION SURVIVAL
- EARLY STAGE INVESTING AND THE RETURN OF THE START UP
- 2004: A PROMISING YEAR FOR BIOTECH
- INDUSTRY MARKETS IGNITING GROWTH
- INSTITUTIONAL INVESTORS SPEAK OUT ON INVESTING AND MANAGING RISK
- SECONDARY MARKET INVESTING
- CREATIVE LIQUIDITY STRATEGIES IN THE CURRENT MARKET
- GLOBALIZATION OF VENTURE CAPITAL & PRIVATE EQUITY INVESTING: THE NEW IMPERATIVE
- CORPORATE INVESTING & PARTNERING: CO-INVESTING & DEVELOPING STRONG ALLIANCES
- WHY PRIVATE EQUITY INVESTORS ARE TAPPING UNIVERSITIES AND NATIONAL LABS FOR INVESTMENT OPPORTUNITIES
- TECHNOLOGY SPINOUTS: CREATING NEW VENTURES OUT OF INTERNAL TECHNOLOGIES
- EMERGING SILICON VALLEY – THE GROWING ASIA PARADIGM

CO-PRESENTING SPONSORS:

PRICEWATERHOUSECOOPERS

TESTA, HURWITZ & THIBEAULT, LLP

SPONSORS:

abd services · ALLEGIS CAPITAL · APV TECHNOLOGY PARTNERS · COMERICA · CRYSTAL INTERNET VENTURES · FOCUS VENTURES · interface SOFTWARE · Microsoft · SHERWOOD Business Continuity Advisors www.shrwood.com · Silicon Valley Bank · TechnoCap · WILSHIRE · WOOD SIDE FUND

To Register: Contact Cathy Fenn, IBF Registrar, at
(516) 765-9005 or via email at Cathy@ibfconferences.com

MENTION CODE: MIT FOR A $100 DISCOUNT

www.ibfconferences.com

International Business Forum
IBF CONFERENCES

HYBRIDS' RISING SUN

This year Toyota will sell 150,000 gas-electric hybrid cars around the world. It's one of the most radical transformations in automotive technology in a century. And with U.S. automakers trailing far behind, Toyota's gamble might just shake up the industry. BY PETER FAIRLEY
PHOTOGRAPHS BY JEREMY SUTTON-HIBBERT

Green power: No longer cramped eco-cars, new hybrids at Toyota's factory in Tsutsumi, Japan, will compete for horsepower-loving U.S. drivers.

www.technologyreview.com

BANNERS TWO METERS TALL outside Toyota Motor's sprawling factory in Tsutsumi, Japan, scream "Hybrid," the word emblazoned over an image of the earth. Inside, beneath signs reading "Yoi shina, yoi kangae" ("Good thinking, good products"), assemblers in blue jackets and white gloves turn out about 400 of Toyota's newly designed Prius hybrid sedans every day.

Apart from the signage, it looks much like any other automotive factory floor—and that's what's remarkable. The Prius, which uses both a gasoline engine and an electric motor for propulsion, gets an average of 55 miles to the gallon—about double the mileage of a comparable gasoline car. What's more, the latest model rolling off the factory floor at Tsutsumi doesn't sacrifice power or comfort and sells for only about $1,000 more than a base model of Toyota's mid-size sedan, the Camry.

And the Prius is only a preview of Toyota's ambitious plans for the new hybrid technology. By the end of this year, the automaker plans to sell a luxury sport utility vehicle using the technology—a hybrid Lexus—in the United States. Within a decade, say Toyota executives, the gas-electric combination could be offered in every category of vehicle the automaker sells, from subcompacts to heavy-duty pickup trucks. "When Toyota's SUVs hit the market, and people see what a really powerful hybrid electric vehicle can do, I think it's going to rattle a few cages," says former General Motors chairman Robert Stempel, who chairs Rochester Hills, MI-based technology developer Energy Conversion Devices.

You can be forgiven for thinking that fuel cells, which use hydrogen to produce electricity, were the auto industry's next new thing. GM and other automakers have for years shown off various versions of fuel cell prototypes that do away entirely with the internal-combustion engine *(see "Electricity-Producing Vehicles," TR December/January 2003)*. But it will be at least five years—and more like a decade, according to many experts—before a fuel cell car is cheap enough for the mass market. Then there's the challenge of storing sufficient hydrogen, the lack of hydrogen filling stations, and the problem of producing hydrogen in the first place. In contrast, hybrids are available now, and they fuel up at the local pump. Toyota alone expects to sell 130,000 Prius hybrids in 2004. Throw in the hybrid Lexus slated for export and a handful of Japan-only hybrid models, and the company's sales of gas-electric vehicles should easily top 150,000—a figure that Toyota says could double by 2006. While that is a small fraction of Toyota's total sales—which hit nearly 6.8 million in 2003—it is still a big number for an unconventional automotive technology.

Indeed, gas-electric hybrids are the first significant break with carmakers' total reliance on the internal-combustion engine in nearly a century. And the implications of a widespread switchover to gas-electric hybrids are immense for both consumers and the auto industry. Even bumping up the average gas mileage of U.S. vehicles to a modest 40 miles per gallon by 2012 would mean the United States could trim its oil consumption by three million barrels per day—more than it imports from all the Persian Gulf countries. And though buyers would have to pay more initially for gas-electric hybrids, they could save, on average, $5,000 at the gas pump over the 15-year life of a vehicle.

From a business perspective, if hybrids take off in the marketplace, Toyota will almost certainly emerge as the player to beat, thanks to its hefty investment in the technology over the last decade. "They have seized the high ground," says Rich Schaum, a former chief engineer at Chrysler. "It's a long-term strategy which may force the hands of their competitors." Indeed, as recently as three or four years ago, GM, the world's largest automaker, was characterizing hybrid cars as a pit stop on the road to fuel cells. But last year GM announced it would have the manufacturing capability to build as many as one million hybrids by 2007, if buyers want them, and that by 2008, it would build three basic hybrid architectures—the platforms for as many as a dozen hybrid car and truck models. Most major automakers plan to bring hybrids to market in the next five years *(see "Hybrids Head for Showrooms," p. 38)*; still, these other manufacturers are badly trailing Toyota, and some competitors are even turning to Toyota's technology: GM and Ford Motor are buying key hybrid parts, such as nickel-metal-hydride batteries and sophisticated transmissions, that were developed by Japanese suppliers in partnership with Toyota.

A little exploring beyond the Tsutsumi factory floor shows how Toyota set all this in motion.

COMING CLEAN

Drive beyond the cluster of auto plants around Tsutsumi and nearby Toyota City and into the hills north of Nagoya, and you find another Toyota plant—this one bereft of banners. At this factory, called Hirose, Toyota did something extraordinary for a carmaker: it built dedicated facilities to fabricate state-of-the-art semiconductor chips. Most carmakers are satisfied to buy off-the-shelf electronics or farm out electronics manufacture to suppliers. Toyota is doing everything in-house. Its high-tech chip plants churn out the power controllers that constitute the

FOSSIL FUEL FRUGALITY: Cars, SUVs, and other "light" trucks emit 16 percent of all carbon dioxide and other greenhouse gases released in the United States. **If every American switched to a hybrid vehicle that got 40 miles to the gallon—up from today's average of 24 miles per gallon—it would cut these emissions by nearly half.** Though unlikely to slow potential climate change, experts say, that might at least offset the extra emissions from the 71 million more passenger vehicles expected on U.S. roads by 2020.

Check my amps: Under a Toyota hybrid's hood, high-power electronics inside a laptop-sized housing govern power flows between motors, batteries, and brakes.

Electric attraction: A visitor focuses on a hybrid displayed in a showroom in Japan.

HYBRIDS HEAD FOR SHOWROOMS

IN THE NEXT FEW YEARS, the six top sellers of cars in the United States plan to roll out a range of hybrid cars and light trucks. New models include "full hybrids," which add all-electric propulsion to the traditional engine, and so-called mild hybrids, in which a less extensive electric system supplements the engine or does things like stop and restart the engine at traffic lights.

■ **DAIMLERCHRYSLER** (Stuttgart, Germany)
Canceled Durango SUV hybrid project in 2002; began fleet sales of mild-hybrid diesel-electric Ram pickup in 2004; experimenting with full-hybrid diesel-electrics

■ **FORD MOTOR** (Dearborn, MI)
Canceled Explorer SUV hybrid introduction in 2001; full-hybrid Escape SUV now due out this summer; full-hybrid option promised for Futura sedan, which debuts in 2005

■ **GENERAL MOTORS** (Detroit, MI)
Canceled full-hybrid VUE SUV promised for 2005; mild-hybrid Silverado and Sierra pickups to debut this year, the VUE in 2006; promising full hybrids, including a Malibu sedan and Tahoe and Yukon SUVs in 2007, and Silverado and Sierra pickups in 2008

■ **HONDA MOTOR** (Tokyo, Japan)
Insight two-seater, a mild hybrid, was first hybrid to reach the U.S. market in 1999; now sells Insight and mild-hybrid Civic worldwide; adding mild-hybrid Accord sedan this fall

■ **NISSAN MOTOR** (Tokyo, Japan)
Test-marketed hybrid Tino compact car with proprietary lithium battery in Japan in 2000; licensing Toyota technology for a possible 2006 full-hybrid Altima mid-size sedan

■ **TOYOTA MOTOR** (Toyota City, Japan)
Launched first hybrid car in 1997; sells full-hybrid Prius worldwide and six other hybrids in Japan; full-hybrid Lexus and Highlander SUVs promised for export by fall 2004 and early 2005; considering full-size hybrid pickup trucks and Camry

hybrid vehicle's heart, making Hirose the centerpiece of a hybrid investment that some analysts peg at $1 billion.

The Hirose plant is off-limits to journalists, but the story of Toyota's program is one that its architect—Takehisa Yaegashi, the unassuming engineer revered within Toyota as "the father of the hybrid"—is eager to tell. Drinking black coffee in a nondescript meeting room in Toyota's offices in Tokyo, Yaegashi traces the origins of Toyota's hybrid strategy back to the early 1970s, when the U.S. Congress set the first national limits on tailpipe emissions.

In 1971, Yaegashi was a 28-year-old mechanical engineer, two years out of Hokkaido University, when Toyota assigned him to its new clean-engine project. Over the next 20 years, he designed everything from exhaust-scrubbing catalytic converters to emission-reducing engine control systems. All this helped make Toyota's fleet of cars one of the cleanest sold in the United States. (The cars in Toyota's 2003 U.S. fleet get an average of 32.3 miles per gallon of gasoline, 3.6 miles more than GM's cars. Toyota's SUVs and light trucks, however, get an average of 21.9 miles to the gallon, only eight-tenths of a mile better than GM's.)

But Toyota didn't stop at innovative catalytic converters. By the early 1990s—even as Toyota followed the lead of U.S. automakers by making popular but fuel-guzzling SUVs—Toyota's leaders prepared to redouble their efforts to clean up the automobile and make it more fuel efficient. "We saw two things happening at the same time: demand for cleaner air and demand for greater fuel savings," recalls Yaegashi.

At the time, the solution seemed to be battery-powered electric vehicles. Toyota built electric versions of its small SUV, while GM test-marketed a sporty two-seater. But neither of these early electric vehicles ever made it to mass production; the batteries limited their range to barely 100 kilometers. Still, these experiments taught engineers an important lesson: you could make electric cars powerful, quiet, and peppy by using high-power electronics to manage the flow of electricity between the battery and the electric motors. As Stempel puts it, "The electronic revolution gave the engineers the tools they needed to make electric cars quite drivable. That broke open the logjam."

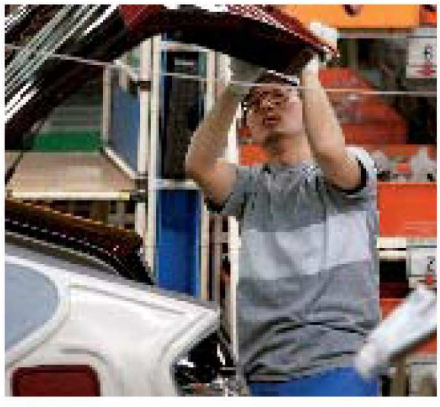
CHANGING LANES

Still, the batteries were a problem. Few consumers would buy cars that needed to be plugged in after less than an hour on the highway. So Toyota's management switched gears and decided to exploit what it had learned to build a vehicle that would outperform traditional all-electric cars: the gasoline-electric hybrid.

The idea was to capture the best of gasoline and electric cars. At low speeds, where combustion engines are at their least efficient and most polluting, Toyota's hybrid uses an electric motor instead. At higher speeds, where an electric motor lacks sufficient muscle, a small gas engine kicks in. The engine can directly spin the wheels or spin a generator to provide electricity. Hybrids also capture energy from another source: the brakes. Touch the brake pedal, and the electric motor switches roles and serves as a generator, transforming the car's kinetic energy into electricity to recharge the batteries. All these tricks are possible because hybrids—unlike conventional cars—have high-power electronics and large batteries.

By 1995 Toyota had unveiled its Prius concept car. Just two years later Toyota's distributors in Japan were selling the

Hybrid ramp-up: A conventional production line in Tsutsumi, Japan, produces about 400 unconventional hybrid Prius sedans every day.



Prius, as well as a hybrid bus. By 2001 they were selling a hybrid minivan and a luxury sedan in Japan *(see "Car Culture," p. 40)*. And in 2000, Toyota began selling an improved Prius in the United States, competing with a hybrid model from Honda Motor, the Insight compact sedan.

Still, Toyota executives felt the hybrids were too sluggish. But whereas Honda boosted the Insight's performance by making it as light as possible, Yaegashi's team revamped the Prius with brawnier electric motors and batteries that can make even heavier cars peppy. They added a smaller, smarter power controller that better regulates the flow of electricity between the batteries, the brakes, and the electric motor and generator. The result is the most powerful hybrid yet, the 2004 Prius—the version rolling off the Tsutsumi assembly lines—which accelerates better than a four-cylinder Camry but gets roughly twice the gas mileage.

Toyota has already announced that in 2004 it will sell a hybrid Lexus SUV, dubbed the RX400h, whose V6 engine will deliver power rivaling that of a V8 but with the fuel efficiency of a compact car, and a hybrid Highlander—Toyota's mid-size SUV—that is more powerful than the gas-only model. And the company hints that hybrid versions of the Camry and even a brawny pickup truck like the Tundra are not far behind.

Toyota's SUVs and minivans exploit hybrid technology to offer yet another payoff: advanced four-wheel drive. Conventional four-wheel-drive vehicles employ a bulky and costly drive axle that delivers mechanical power to the rear axle through the familiar hump on the cabin floor. On optional four-

CAR CULTURE

TOYOTA SELLS SEVEN gasoline- and diesel-electric hybrid vehicles in Japan, from subcompact cars to delivery trucks. When I asked to drive them all, Toyota officials brought me to the company's very own automotive theme park, called **Megaweb**, on the Tokyo waterfront.

At Megaweb, which is a hot dating spot for Tokyo teens and twentysomethings, you can test your skills in sophisticated hydraulic driving simulators, explore the History Garage jammed with vintage cars, and tour various eateries via electric cars that communicate wirelessly to avoid collisions. And then there's Megaweb's cavernous glass and steel showroom sporting all 80 Toyota models of car, van, and SUV.

But the centerpiece is a 1.4-kilometer test track. My test drives began with a dark red Prius, delivered to the starting lane by a Megaweb pit crew in jumpsuits. A green "ready" light on the dash reminded me that starting a Toyota hybrid is like turning on a DVD player: the electromechanical vehicle tests its circuits, powers up its display, and awaits command. I punched the Prius's electronic shift control up to *D*, stepped on the pedal, and, pit flags waving, entered the track.

A touch-screen display on the dashboard explained what was happening under the hood, showing how electrical pulses were flowing from the battery to the electric motor to the wheels. As we cruised past Megaweb's 40-kilometer-per-hour speed limit, the gas engine kicked in seamlessly. When I hit the brakes at a red light, the dashboard display showed that the wheels had become a power source, spinning a generator to recharge the batteries.

Next up was a light-green metallic Estima minivan, a hybrid with a twist: electric motors on both axles and an electronic traction system enable the vehicle to monitor and adjust the power to each wheel in real time. It certainly felt good to zip up and down the track at Megaweb in a van that gets 44 miles per gallon. (Toyota has sold more than 22,000 hybrid Estimas in Japan since their debut in 2001. But the Estima is considered underpowered for the U.S. market.)

By the time I was done at Megaweb, I had driven another minivan and a hybrid luxury sedan. But by the 10th lap, I had had my fill of maneuvering my way around the piazza and trying to beat the traffic signal. So I blew through the red light. Toyota's hybrid technology was happy to oblige.

Voltage view: An in-dash display shows a hybrid's electricity flows.

wheel-drive models, Toyota's hybrids feed power through a high-voltage cable that drives an electric motor on the rear axle, freeing up cabin space and making the vehicle more stable by deftly adjusting the torque on each wheel by the millisecond.

So is the $1 billion bet paying off? Yaegashi laughs and demurs. "I hesitate to say we are very much ahead of the others, but I do want to emphasize the difference between Toyota and the other companies," he says. "We have a six-year advantage in mass-producing hybrids."

TAILGATING

Catching up looks like a bumpy road for other automakers. Even Honda, probably Toyota's most advanced hybrid competitor, has its work cut out, according to industry experts. "When it comes to engineering the system as a whole, I think Toyota has three, four years' advantage over the others, even compared to Honda," says Koji Endo, a Tokyo-based auto analyst for Credit Suisse First Boston. Honda's models—which include a hybrid Insight and Civic, and an Accord due this year—have less electrical power and are more expensive to produce than Toyota's, Endo says.

Detroit's Big Three are farther behind. Over the last two years, GM, Ford, and DaimlerChrysler have scrapped or delayed half a dozen ambitious hybrid projects. "What they're learning is that making this transition to electric drive technology is not going to be a piece of cake," says Dan Sperling, director of the Institute of Transportation Studies at the University of California, Davis. "You can't just say, 'Okay, I'm going to build a hybrid car,' buy the technology, and put it out there next year."

Last year, Ford delayed the release of its debut hybrid: a version of its Escape SUV. John Kassakian, director of MIT's Laboratory for Electromagnetic and Electronic Systems, which researches automotive electronics, says Ford is paying the price for its early attempts to shoehorn hybrid technology into existing vehicles. Unlike Toyota's hybrid SUVs, for example, Ford's four-wheel-drive Escape hybrids will not have electric motors on each axle, which Ford says would require costly retooling. "Modifying an existing vehicle looks on the surface to be the most efficient way of getting from point A to point B, but you don't end up with a solution that's optimized for cost and performance," says Kassakian. Ford now says it will sell the SUV this year.

Still, the Big Three and other automakers' decision to finally pursue gas-electric hybrids is itself notable. Until recently, GM considered its money better spent on fuel cell technology. It invested hundreds of millions of dollars in fuel cell R&D and rolled out a radical prototype fuel cell car that it has promised to mass-produce by 2010. "More-efficient petroleum-based vehicles alone will not solve our petroleum dependence problem. We believe long term you've got to get to energy sources beyond petroleum, and that's why hydrogen is so attractive," says Larry Burns, GM's R&D vice president. But even Burns acknowledges that automakers need to master hybrids, too, if only for competitive reasons. "We don't know for sure how big the hybrid segment will be—I don't think anyone can predict that right now—but we want to give our customers the choice," he says.

Sales on track: In Toyota's Tokyo showroom and amusement center, called Megaweb, an autonomous car cruises around a track.

High-power vision: Takehisa Yaegashi, Toyota's "father of the hybrid," says the company has a six-year technological head start.

FUEL CELL FUTURE

At Japan's bustling Nagoya Motor Show late last year, Toyota showed off three concept cars. One was a metallic-blue SUV, another an open-topped, bone-white sports car. Both were gas-electric hybrids. But the spotlight finally fell on a metallic-blue hybrid sedan with a twist: it uses a fuel cell, not a gas engine.

Toyota calls it the Fine-N, and it uses many of the tricks that the company has learned from its gas-electric vehicles. "Clearly, the [hybrid] technologies that we're pursuing—the motors, the power electronics, all the logic it takes, even the art of caring for the batteries—are essential elements of the fuel cell vehicle," says Schaum, the former Chrysler chief engineer, now a vice president at electric-motor developer WaveCrest Laboratories of Dulles, VA. "You really have to master this before you are ready for the hydrogen economy."

If he is right, Toyota's early dominance of gas-electric hybrids could give it a strong head start toward the future. Every automaker is spending heavily on developing fuel cell cars, and Toyota is no exception—even as it races to dominate hybrids. If it winds up dominating fuel cells, too, it could rob Detroit of its last, best chance to regain its footing as a leader in automotive technology.

Still, no one at Toyota is forgetting today's marketing realities. At Nagoya, Toyota's presentation of its futuristic hybrids-to-hydrogen vision was accompanied by a standard industry touch. As if to suggest that advanced fuel-cell cars are ready for the mainstream, Toyota trotted out young women known as "show companions" to demonstrate the Fine-N prototype. On a spinning platform, a woman in a short skirt and high boots opened the car's rear door, stepped into its rear seat, punched a button, and reclined out of view. It may be at the vanguard of advanced automotive technology, but Toyota hasn't forgotten what sells cars.

Peter Fairley, a *Technology Review* **contributing writer, covers technology, energy, and the environment from Victoria, British Columbia.**

35,000ft.

At 35,000 feet,
product development
is about designing
high quality products
that never need recalls.

30,000ft.

25,000ft.

20,000ft.

15,000ft.

10,000ft.

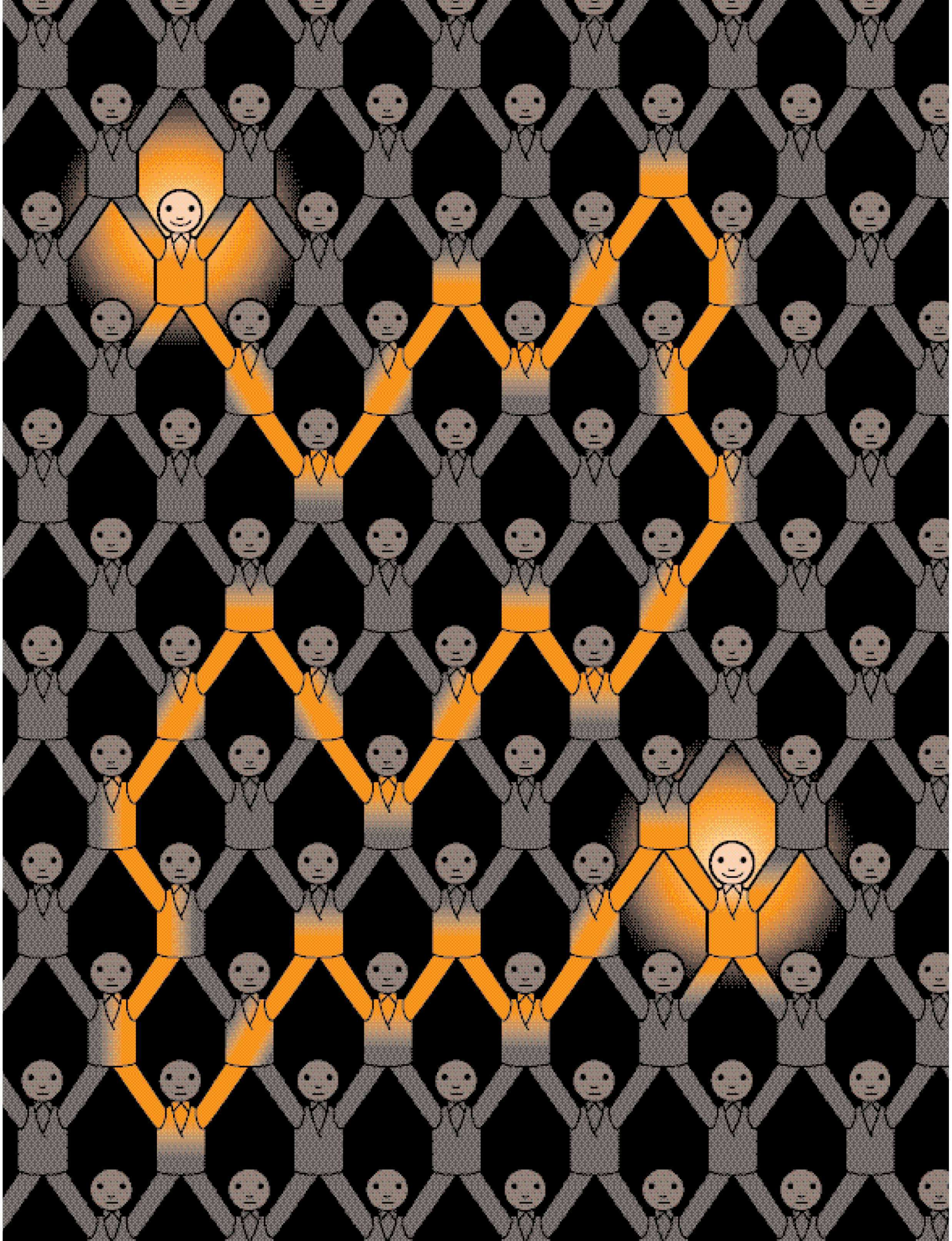
5,000ft.

0

At ground level,
product development is about
releasing a design to manufacturing
with full confidence that the product
will work. No surprises.

Confidence. You get it by being able to explore more design iterations in digital form, before costly manufacturing of your physical product. You get it by involving your suppliers and customers in the process, and still managing every aspect of product information throughout development. Create. Collaborate. Control.™ It's what you must do to innovate with confidence, and only PTC offers these three key product development capabilities in an integral product development solution. To learn more, join an executive seminar presented in partnership with MIT's Technology Review. Visit **ptc.com/go/mitseries** for details.

PTC®
The Product Development Company™



INTERNETWORKING

A NEW WAVE OF SOCIAL-NETWORKING SOFTWARE IS HELPING PEOPLE FIND FRIENDS, GET WORK, AND CLOSE DEALS BY HIGHLIGHTING THE HIDDEN CONNECTIONS BETWEEN USERS—AND THIS TIME, ITS INVENTORS SAY, IT'S NO DOT-COM DELUSION.

BY MICHAEL FITZGERALD

ILLUSTRATION BY CHRISTOPH NIEMANN

IT'S A GRIM January day here in Oakland, CA, but Justin Phelps is grinning so wide it practically shows through the phone. "It's about 80 degrees, blue skies, there's a couple of cruise ships in the water," he says. "It's perfect."

Phelps is in Grenada, but he's not on vacation. He's the new chief technology officer at Blue-Stream, a Caribbean telecom and Internet provider, and he's describing the world outside his office window. Not long ago, the 28-year-old was about to become yet another unemployed Bay Area dot-com casualty and was packing up for a six-month trek in South America. But then he logged into Tribe.net—an online social network where he'd set up a profile of himself and his interests and built a network of connections. A friend on Tribe had sent him word of the Blue-Stream job after hearing about it from another Tribe member he knew from the site's yoga interest group, which happened to include yet another member who knew a Blue-Stream director.

That's a lot of connections to follow, and Phelps's experience may be extreme; in fact, Tribe.net features his testimonial on the front page of its Web site and has directed several journalists his way. But it demonstrates what can happen when people's real-world social networks are enhanced by computer-mediated ones. Software like Tribe's helps users create, map, and exploit a web of social and professional acquaintances much broader than the ones they maintain in everyday life. And those webs are good for more than just finding jobs: businesses are starting to use them to dig up sales leads and close deals.

The premise behind this new social-networking technology is simple: you may know a lot of people from work, college, church, or your neighborhood, but you probably don't know exactly who *their* friends are—and forget about their friends' friends. But join an online social network and invite a few acquaintances, and the software will begin to reveal previously hidden second- or third-degree connections that can lead to an interview, business meeting, or tee time with that elusive potential client or employer.

With venture capital firms lining up to invest, and more than a million subscribers already signed up, automated social-network analysis has become one of the hottest trends to hit information technology since the dot-com bubble. That's despite the fact that when the bubble burst, it took with it an earlier wave of social-networking-software companies, destroying millions in equity. Those first-generation companies, such as sixdegrees, PlanetAll, and BranchOut, had good ideas but bad timing, the new innovators and their backers believe. While the companies proved that people were interested in easier ways of connecting, whether for a job search or just to hang out, it was also clear that users had to work too hard to build those networks; for example, many users had to manually upload contact information from their paper Rolodexes or address books.

Today, "Eighty to ninety percent of [real-world] social networks have a digital component," be it an archive of e-mail correspondence or vital statistics logged into a sales force database, says Antony Brydon, president and cofounder of Visible Path, a New York firm that's developing social-networking applications for corporations. These digital trails mean that human connections can be plumbed, downloaded, and mapped automatically—so companies like Visible Path can help clients take better advantage of their employees' business relationships.

By some counts, more than 30 social-networking startups have been launched in the last three years, backed by tens of millions of dollars in venture investments, and their services go well beyond those of the now familiar dating sites like Friendster. Visible Path has raised $3.7 million in venture capital, with investors including technology industry seer Esther Dyson and several high-tech executives. Rival social-networking firm Spoke Software, meanwhile, says it has collected a tidy $20.9 million.

This second wave of networking companies could still crash, especially if they can't entice people or businesses to pay for their services over the long haul. But technologists and investors are adamant in their belief that things are different this time—and not just because more people have their contacts stored electronically. It's also because the new companies are being more cautious with their cash, and because consumers are more wired now than they were five years ago. If nothing else, there is a strong sense that software that maps social networks is so useful that other, larger software and Web companies will eventually add it to their own offerings. Social networks, like multimedia, will simply become a part of the online experience, says Marc Canter, founder of multimedia-software giant Macromedia and now head of Broadband Mechanics, another San Francisco social-networks developer. "It's going to be a feature, and everybody will have it."

ANTONY BRYDON
President and cofounder
Visible Path
www.visiblepath.com

Visible Path's software scans employees' desktop applications for data on their relationships with people outside the company and builds an "enterprise network map" that can, for example, steer a salesperson along the strongest chain of connections to a prospective client.

MARK PINCUS
CEO and founder
Tribe.net
www.tribe.net

At Tribe, as at most social-networking sites, people create personal and professional profiles, then invite friends to create connected profiles, forming personal networks that can be used to exchange referrals such as job interview or sales call requests.

SIX DEGREES OF PREPARATION?

People have always had their own social networks, of course, but these networks weren't explicitly mapped until the last century. In the 1930s, a psychiatrist named Jacob Moreno invented the sociogram, a series of dots and lines showing people's social connections. Neat idea, hard to do: a single sociogram typically represented hours of laborious interviews. Harvard University psychologist Stanley Milgram's famous 1967 finding that on average we're only six acquaintances away from anyone else on the planet was still almost 30 years ahead of the technology needed to take advantage of it.

Finally, in the mid-1990s, powerful networked computers became widespread, e-mail began to displace the telephone for many types of conversations, and the Web started to emerge as a kind of electronic reflection of communities, businesses, individuals, and their interests. Entrepreneurs saw an opportunity to help people make more of their electronic connections. That was the concept behind sixdegrees, launched in 1997, which at its height counted more than three million members in its network. At the time, however, advertising was the main source of revenue for Web companies; when online ad revenues failed to grow, so did sixdegrees, which was purchased by YouthStream Media Networks for $125 million in stock in 2000 but shut down a year later.

But the ideas are back, and in spades. Post-bubble trauma is finally fading; home broadband connections reach 38 percent of U.S. Internet users—almost 50 million people, up from virtually zero in 1997; and the spread of programs like Microsoft Outlook means that most home Internet users and office workers already have the names and addresses of their acquaintances compiled in electronic form. "Social networking was a good idea then, it's a good idea now, and it'll be a good idea in 2011," argues sixdegrees' founder Andrew Weinreich, who's now a Visible Path advisory-board member. "*This* is the time for it."

LinkedIn, a business-focused networking site operating from Mountain View, CA, is fairly typical. Users create a profile on the site, which can be as basic as a name and a set of business interests or as broad as an entire work history. They can then search for people they know on the site—typing names or affiliations into the LinkedIn search engine—and invite them to join their networks. Users can also send e-mail through LinkedIn and directly invite friends and colleagues not already signed up to join their networks by creating LinkedIn profiles of their own. Invitations can be created piecemeal or by uploading entire e-mail contact lists to the site. LinkedIn's software can automatically send and track invitations and issue reminders to people who are slow to join.

Once connected, users gain access to their friends' connections and can use LinkedIn's search engine to search the resulting network for, say, officers or employees of a specific company. If a search produces the name of someone they'd like to meet, they can use the network to ask for an introduction. Contact information is kept private, so requests must be sent through the chain of members linking the inquirer and the target. The bottom line: it becomes extremely easy to search, view,

TIM CONNORS
Founder, board member
Spoke Software
www.spoke.com

Spoke's software, like Visible Path's, captures relationship data already stored in employees' e-mail and other business information systems and discovers second-, third-, and fourth-degree connections that can be exploited to streamline the sales process. Spoke's system also allows business users to tap into a general public network that includes thousands of independent professionals.

MATT PETOSA (BRYDON); EMILY NATHAN (PINCUS AND CONNORS)

and contact all of your online acquaintances—and their acquaintances, out to four degrees of separation (anything more remote is generally not useful, social-networking insiders say).

It might sound a bit convoluted, but it's simple in practice—and users claim that they get tangible results. Take Marcus Colombano, a media and technology marketing consultant in San Francisco. Colombano read about a company he thought should be a client, popped its name into LinkedIn, and found he was connected to four people with contacts at the company. He wrote up a proposal and sent it to a friend who had a contact who knew the CEO. Four hours later he got an e-mail from the CEO asking for a meeting. "I'm going to get an opportunity to sit down and do a proposal with these people," Colombano says. "It's really quite cool."

YOU MAKE $, I MAKE $

Will cool—and quick—intros for clients translate into cold cash for the networking firms? That's an unanswered question, as most public networking sites are still in some form of beta testing and aren't yet charging for membership or services. LinkedIn, for instance, says it will charge an as yet undetermined amount for referrals and other types of connections. San Francisco-based Ryze, which grew out of a real-world networking club and is the oldest of this second generation of social nets (dating back to October 2001), only charges for premium services, such as access to advanced search tools that can find people by company, university, and interests. It also earns revenue from its real-world mixers and claims to be profitable.

One thing is certain: today's networking sites are growing at a more sustainable pace than their predecessors. Sixdegrees raised $26.5 million and employed 85 people, all working in expensive Manhattan office space, before being shut down at the end of 2000. By contrast, "It's freezing in my offices," says Mark Pincus, founder and CEO of San Francisco-based Tribe.net and a veteran of two bubble-era startups. "I have to wear a coat. I think we might be going too far to the other extreme, being too conservative in spending money."

Veteran venture capitalists agree that things are different with this round of startups. Allen Morgan, a general partner at the Menlo Park, CA, venture capital firm Mayfield—which, along with Knight Ridder and the Washington Post Company, invested $6.3 million in Tribe—points out that users generate the content of the social-networking sites and provide most of the marketing by word of mouth, so the companies can run on the cheap. He calls that "a good bet."

At the same time, other Web businesses from Yahoo! to craigslist, a classified-ad site based in San Francisco that charges $75 to post a Bay Area job listing, have proved that people will pay for certain online services, such as personal ads. The networking sites will likely go after a chunk of that business. "Tribe will cannibalize the online-classified-ads market and a portion of eBay's [auction] market, and LinkedIn will cannibalize both online and offline recruiting," predicts Ross Mayfield (no relation), a technology blogger and CEO of Socialtext, which makes group communications software. Each of these niches generates hundreds of millions of dollars in annual revenue, though to get their share of it, the social-networking companies must still figure out how much to charge, and for what.

MAKING THE SALE SOONER

While the social-networking sites show promise, however, they are unlikely to capture all of our connections. There will always be people who decide not to join any network. And prominent people often don't want to make themselves easier to find: you shouldn't count on running across a Warren Buffett or a Bill Clinton at LinkedIn or Friendster.

But many key connections might just show up in networks built with more sophisticated analytical tools. As businesses have moved onto the Internet and become more dependent on software for communications, they've already digitized huge amounts of contact data, in the form of e-mail archives, calendar appointments, corporate phone lists, customer databases, and Web pages. Companies like Spoke Software of Palo Alto, CA, are building applications that automatically sort through this data and then apply social-networking-analysis techniques to weight connections and generate "corporate sociograms" showing the strongest paths

SOCIAL NETWORKING'S SKEPTICS

Four experts identify pitfalls that could keep consumers and businesses from warming to the new technologies.

"Privacy is going to be a big issue. Some of the social-network services don't put users in control of their privacy. These networks are not just personal data about you; it's personal data about you and someone else. That'll be a different gray area for most users, who are in some cases submitting data about their friends without their knowledge. All it takes is one horror story."

ROSS MAYFIELD, TECHNOLOGY BLOGGER; CEO, SOCIALTEXT

"If anybody six degrees from you could get your attention, you'd be time-spliced to death."

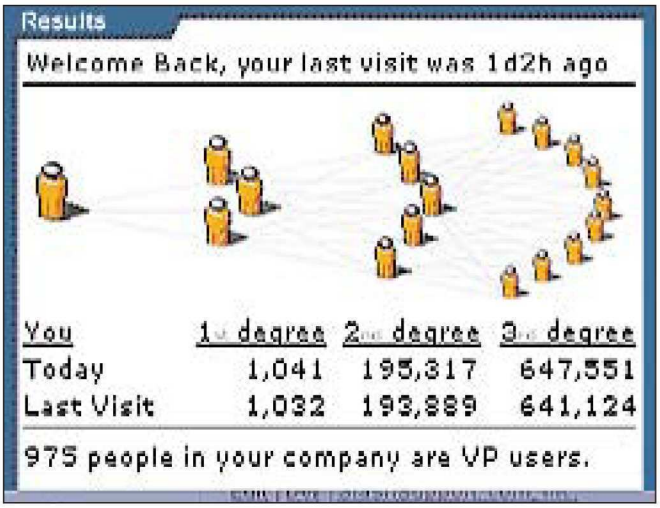
CLAY SHIRKY, INTERNET CONSULTANT; ADJUNCT PROFESSOR, INTERACTIVE TELECOMMUNICATIONS PROGRAM, NEW YORK UNIVERSITY

"If you mess with how people naturally network, you're going to turn a lot of people off, and you're not going to get them to board your boat. If the people [I] add don't respond, they're not in the network. I can put in my 50 best contacts, but if only 20 respond, then my network doesn't exist. And most people will not choose to put their best 50 contacts in. So the networks are not realistic."

VALDIS KREBS, MANAGEMENT CONSULTANT; SOFTWARE DEVELOPER; PRINCIPAL, ORGNET.COM

"Social-networking-analysis software is all about the digital world, not the real world. Eighty percent of what's important in our interaction is physical, so all the good stuff isn't in [these networks]."

ALEX "SANDY" PENTLAND, DIRECTOR, HUMAN DESIGN GROUP, MIT MEDIA LABORATORY



Getting to know you: Visible Path's software shows employees how many people they can reach through colleagues or friends of colleagues.

COURTESY OF VISIBLE PATH

to target customers. Mapping those relationships can get salespeople in the door more quickly, freeing them from low-yield activities like cold calling. In fact, the software should help close sales almost 25 percent faster, the companies claim.

Tim Connors, a venture capitalist at U.S. Venture Partners, got the idea for Spoke when he saw how hard it was for technology startups to get the time of day from their target customers—corporate information technology managers. He realized that no tool existed to help with this problem, so he started recruiting programmers to build a public networking site that infotech insiders could join. But Connors's first choice for technical whiz, Andy Rosenbaum, was concerned that the new network would run into the same revenue problems that sixdegrees had. "I was like, 'Who's going to pay for it?'" Rosenbaum says. Connors responded by adding features directly aimed at sales departments—most importantly, the ability to build a closed, proprietary network of contacts, supplemented by access to the public network. Rosenbaum, however, needed a stable job to help support impending twins and went to Yahoo! to build its personal-ads service. But within nine months, Connors had won venture funding for his project, and Rosenbaum was sufficiently wowed by Spoke's prototype to join the company as chief architect.

Spoke launched its software in October. Rather than charging a standard license fee, it collects a percentage of the sales revenues it enables. It was building proprietary networks for two corporate customers by the end of 2003 and had signed contracts for trial-run projects at another eight companies, typically for $50,000 to $75,000 each.

Spoke's closest rival is Brydon's company, Visible Path, whose development team is squirreled away in a back room with eight cubicles and a conference table in a bland office building in Manhattan's Chelsea neighborhood. Chief technology officer Jeff Patterson and platform architect Cliff Rosen worked on the company's software with Stanley Wasserman, a University of Illinois statistician who literally cowrote the book on social-network analysis—an 857-page tome that's considered the leading text in the field. Unlike other social-network products, Visible Path is only available to companies and only plots data from their internal resources. Its software runs on a network server and communicates with a small program installed on each employee's PC that works in conjunction with a standard Web browser. This plug-in monitors the employee's communications and sends data back to the server, where it's folded into social-network maps that all employees can search. The system, which is being tested by about a dozen beta customers, gauges the strength of each relationship based on things like which e-mail messages users respond to, how long it takes them to respond, and what acquaintances they have in common.

Corporate executives say the potential for increasing revenues is obvious, and big. "It's intuitive that these relationships exist within corporations," says an executive at one mid-size company testing Visible Path. "I have a lot of contacts, and rarely does sales call me to ask who I know." He says Visible Path is beginning to change this: in his company's first three weeks using the software, he received two requests from colleagues in the sales department asking him for introductions to people the software said were close to him. In both cases these were, in fact, people he knew well enough to get the salespeople in the door.

It's too early for the executive to say whether Visible Path's software will deliver on its sales promises. But from what he's seen of its ability to correctly gauge contacts that can be parlayed into meetings, he's optimistic that some type of social-network analysis will soon help his company close lucrative deals. When that happens, he says, "There is no question we'll spend money on it."

FACE TIME

The social-networking companies' early successes will be solidified if they can figure out the answers to a few open questions. One is about cooperation. Today, if consumers or businesspeople want to tap into online social networks maintained by different companies, they must fill out new profiles and send out new connection invitations in each. But many users wish they could make their networks larger and more varied by creating connections across the boundaries of sites like LinkedIn, Ryze, and Tribe. A data standard being developed by independent programmers called "Friend of a Friend"—a way to create a short, machine-readable file that resides on the Web and provides your personal data and the names of your connections to any software that requests it—promises to make such internetwork connections easier, but it has been slow to roll out.

The biggest questions, though, are sociological as much as technical *(see "Social Networking's Skeptics," p. 48)*. For instance, will computer-generated social-network maps ever truly reflect real-world networks? Valdis Krebs, a management consultant and software developer who has nearly 20 years of experience with social-networking software, thinks corporate social networks will always miss the nuances that matter in the real world. Often, a network map won't come up with a reliable chain of connections to a potential client an employee wants to target, or "we find out that someone is difficult to work with, or they give you stuff that's not what you need," says Krebs. "A day face to face is worth a thousand e-mails."

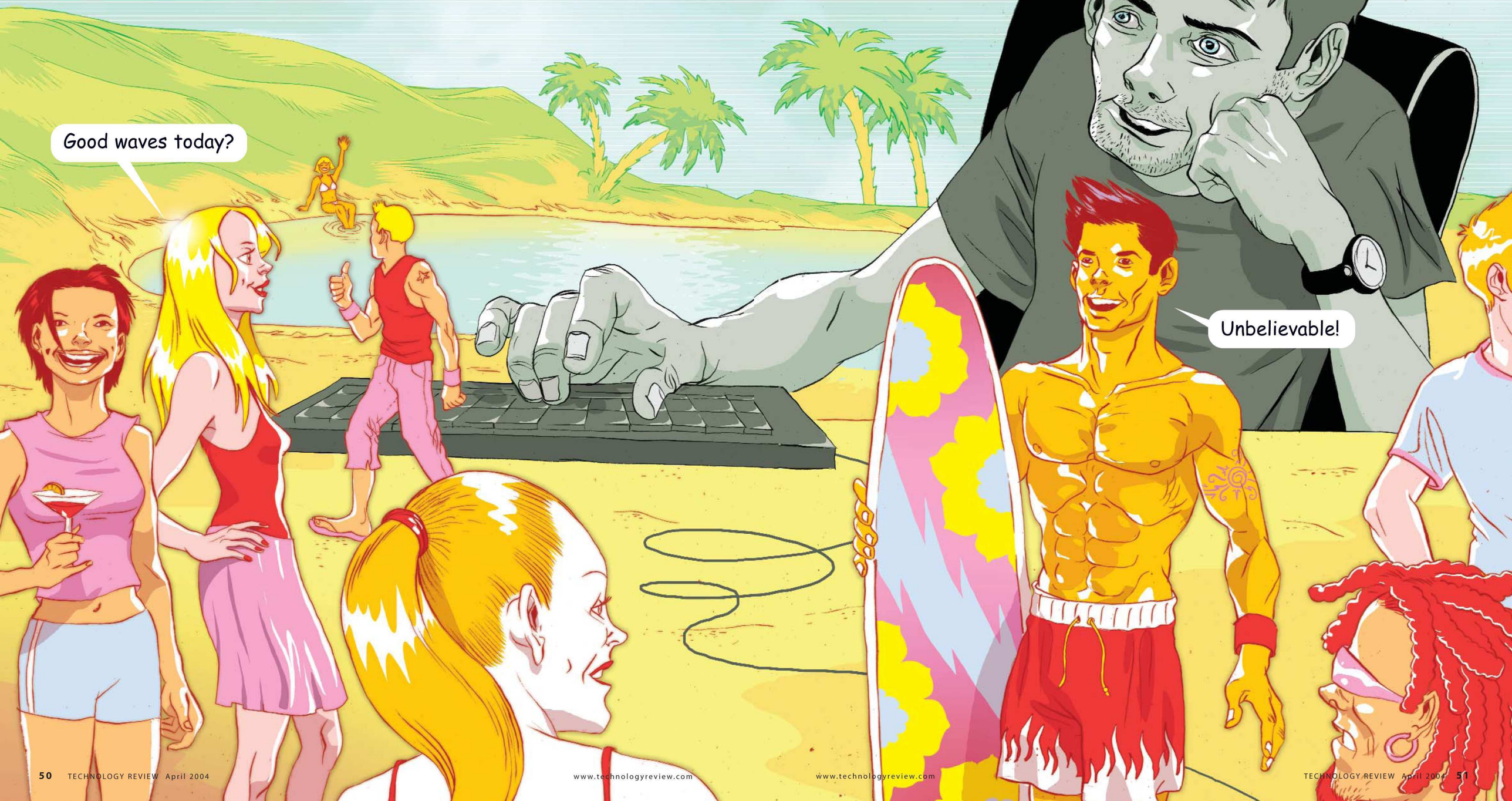
Maybe so. But then again, if an online social network can help get you the face time you need, you might just wind up with a great gig in the Caribbean. TR

Michael Fitzgerald is a freelance journalist in Oakland, CA, who writes frequently about business, technology, and the San Francisco Bay Area.

My Avatar, My Self

Forget smiley faces. Inhabitants of virtual worlds are donning 3-D graphical personas and finding whole new ways to mix it up with other folks—and their simulated online experiences point to where digital socializing is heading.

BY DAVID KUSHNER ILLUSTRATIONS BY TOMER HANUKA



IT'S A QUIET DAY OVER HERE. The ground outside my window is caked in snow. The driveway is icy, the car waiting to be freed. Short of the UPS guy or maybe the neighbor walking his twin dachshunds, the chances of chatting up someone about last night's episode of *Curb Your Enthusiasm* seem slim.

But as always, there's plenty happening over *There*. The dune buggy racers are kicking up dirt on their way to the track. The hoverboarders are flying. A surfer dude flirts with a raver in a halter top and neon green micro shorts. And Lexxa, someone who has greeted me within seconds of my materialization, is offering to show me the way to the spa. "You look like you could use a makeover," she says.

I don't take it personally. She's referring to my avatar—the character I've chosen to represent me on-screen. I'm in There, the most ambitious virtual world yet. Created by a coterie of programmers, Silicon Valley moguls, and Hollywood animators, who have raised about $37 million (and endured at least one round of layoffs), There is a big gamble on one little idea: that the future of online communication looks like a video game. But it's not a game. People don't come here to battle dragons or ogle Lara Croft. They come to hang out. They come to socialize. And they come for the hot tubs.

Over the years, the quest to build a compelling virtual world has been a case study in vaporware. Lame graphics, clunky design, and ghost-town populations have all but shattered the dream of a real-life Metaverse. But times have changed, insist the creators of There and Second Life, a competing virtual world launched last summer. They contend that technology, business, and culture have finally caught up with expectations. Instant messaging and e-mail are middle-American mainstays. Broadband use is on the rise. Computer processors are fast and cheap. "We made some bets years ago," says Will Harvey, the Stanford University engineer who in 1998 founded Menlo Park, CA-based There. And now, he says, "we're fortunate that those bets turned out to be true."

For people like Harvey, this is more than just another fad; it is a whole new style of online personal interaction that could become as commonplace as e-mail. "When we imagine 10 years out," he says, "the time people will be spending on the Internet will be inside a rich visual medium. There's going to be some underlying platform that's making that possible. We think we're making it." Then again, if you had just wagered millions of dollars, you'd put on an optimistic face too.

Over at the spa, Lexxa helps me reconfigure my avatar. A few clicks bring me to a full menu of options for modifying my appearance. I lengthen my nose and broaden my chin. With another click, I ditch my default khakis for a pair of Levi's. When I ask Lexxa what she likes so much about being here in There, the text of her answer fills the word balloon over her head without hesitation. "It's the people," she says.

TO GAME OR NOT TO GAME

Virtual worlds are certainly nothing new. Science fiction writers from Ray Bradbury to William Gibson have long imagined them. Early denizens of the Internet experimented with them in the form of "multiuser dungeons," or MUDs—fantasy role-playing exchanges acted out through online text messaging. Cartoon-style chat worlds like the Palace and Worlds Away had a go in the mid-1990s but never quite caught on.

More recently, massively multiplayer online computer games, such as EverQuest and Asheron's Call, have picked up the slack by emphasizing team play and community. Participants meet in these fantasy-themed online worlds not to compete but to hang out. As a result, one of the missing links that caused earlier virtual worlds to crumble seems to be emerging: an audience. According to the technology research firm IDC, 87.3 million people will be playing online games in 2004. Around 400,000 are paying $13 per month to play EverQuest, by far the most popular pay-to-play game. And these online games have become the training wheels for virtual worlds.

One notable game that styled itself as a virtual world, however, has not succeeded: the Sims Online, the Net-based version of the bestselling simulated-community software from Electronic Arts. The Sims Online is fun, but its problem may be that it's too gamelike. To earn rewards and even to survive, players must perform certain tasks—including mundane stuff like taking showers and cleaning up after dinner—when, it seems, all they really want to do is chat about *American Idol* and have cybersex.

The new breed of virtual worlds aims to deliver a social distillation of the Sims Online, without the dirty dishes. "I want to engage people at a different level than a game," says Philip Rosedale, founder and CEO of Linden Lab, the creator of Second Life. The key insight of the new virtual worlds is to allow people simply to share experiences with fellow cyber travelers, without forcing them to perform any particular tasks. Hygiene, in the new worlds, is a personal choice—not a survival skill. Rather than pitting people against one another, Rosedale says, the new software gives them the tools to express their personalities. "What's interesting is creating a space that can be meaningfully altered to reflect your ego," Rosedale says.

For Harvey, who generally agrees, that's a matter of taking the best of chat and the best of gaming to forge something completely new. For example, he says, "video game skiing is all about getting to the bottom of the hill. But in real life, the experience of skiing is so much more. It's about getting a beer afterward, talking to someone on the lift. It's those situations when so many different aspects of your personality come through."

THE TECHNOLOGY BEHIND THE VIRT PARK. TO SUCCEED, IT MUST WORK

VIRTUAL WORLDS, REAL TECHNOLOGY

Take flying, for instance. Being airborne is kind of cool—even if you're only doing it on your computer. I discovered my powers of flight by accident. I was hanging out in Second Life, the virtual world from Linden Lab, pointing and clicking around until, suddenly, my character on screen was lifting into the sky. Houses, trees, and hills passed beneath me. When I landed, the first thing I talked about was my lame flying skills. The virtual world feeds upon itself, providing shared experiences that its inhabitants can chat about. That's the essence of what's being retailed here, and There. While text chat gives people a way to discuss what's going on in the physical world, virtual worlds give

UAL WORLDS IS SOMETHING LIKE THE ENGINEERING BEHIND A THEME WELL ENOUGH TO CREATE A REASONABLE SUSPENSION OF DISBELIEF.

you things to talk about, too—assuming you have the patience for, and interest in, participating in this consensual cartoon.

In this sense, the technology behind the virtual worlds is something like the engineering behind a theme park. To succeed, it must work well enough to create a reasonable suspension of disbelief. The virtual world needs to be complex but seamless. You need to be able to fly over a hill without crashing to a halt while the next slice of landscape loads into the computer's memory. In the past, virtual worlds were simply not visceral enough to elicit even a hiccup of belief. Floating around a room as a disembodied smiley face, as players did in Palace, was, at best, cute; the technology could not deliver anything even remotely as compelling as a *SuperFriends* rerun. Though technology is catching up, Harvey says, "It's a very difficult technical problem to provide immediate responsiveness and a fast-action feel to people who are playing with others over the Internet."

There and Second Life solve this problem in different ways. Second Life subscribers first download a small (only about 18 megabytes) piece of software called a "thin client." The other 320 gigabytes of data needed to simulate the virtual world—such as richly rendered 3-D graphics and high-fidelity sounds—sit on a grid of servers at Linden Lab's San Francisco facility. Rosedale, who ran the engineering department for RealNetworks, the Seattle-based Internet media company, developed a 3-D stream-

ing technology that delivers all the objects in the virtual world over the Internet in real time. When a subscriber logs off, the virtual world keeps on going and evolving. Log back on and things have changed in your absence.

But continuity is only one requirement for a convincing online environment. For added gravity, There employs a technology called a physics engine that enables objects and avatars to interact as in the real world. Cars collide. Paintball pellets lob through the air. Physics exists. The problem is that you have all these people in the real world, connecting to the Internet through different machines, at different speeds. How do you keep everything moving around convincingly?

The answer, for There, is essentially to stagger the simulation. Rather than conjuring up the world as a single moment in time, the servers keep track of all objects as a series of time points. When I walk next to Lexxa, for example, I see her as walking slightly ahead of me, while she sees me as walking slightly ahead of her. By rendering our experiences individually, the software convinces us that we're in sync, just as if we were taking a stroll in real life.

But more problems persist—the foremost being that these worlds are very big. If Second Life existed in real life, it would cover roughly eight square kilometers. Rather than handling this as one large chunk of data, Second World's software divides it into dozens of 6.5-hectare "tiles." Each tile is maintained by a single Pentium 4 computer, running Linux, at Linden Lab's offices. The computer handles everything from the weather patterns to the scripts that make doorbells ring. As I fly from one tile to the next, information about my surroundings is provided by another server—but for me, the transition is seamless. And as the number of users grows, the world itself expands to accommodate them. "We put new machines online as new users join the system," Rosedale says. "It scales."

Like those at Linden Lab, There's servers partition its world into chunks, or sections, that are streamed to the user's computer. But the partitioning is based on population density rather than geographical area. "If no one is in the Atlantic Ocean," Harvey says, "then the servers can make the entire Atlantic one section. But if the more popular areas have thousands of people in them, then they have to partition in smaller pieces."

Linden Lab and There also provide technology aimed at fostering the kind of community that sprouts naturally around chat rooms. There utilizes so-called avatar-centric communication. When I wander toward some thermal springs and encounter a group of people, my avatar is automatically positioned to face them and theirs to face me, our heads angled inquisitively, our eyes ready to lock. Once you're engaged, you can select from a palette of preprogrammed gestures. I can choose to yawn when bored or wag my tongue if I feel like flirting in a Neanderthal sort of way. Though the expressions are canned, they evoke more intuitive responses than the trite "emoticons" of text-based chat. You don't type a semicolon; you wink.

SHOW ME THE MONEY

I'm suffering from a bad case of hoverboard envy. Just a short time ago I materialized in There, and I'm already itching to upgrade my hoverboard. In these emerging virtual economies, you have to buy such upgrades and other stuff with virtual cash. There issues every member 10,000 "Therebucks" when he or she joins; you can earn more through in-game jobs and transactions. It doesn't take me long to blow several thousand Therebucks on clothes and shoes, like my new Nike sneakers (which Nike made available through an advertising deal). And then there are the big-ticket items: a hoverbike costs around 17,000 Therebucks, a buggy 10,000 to 20,000.

Whoever is operating Lexxa widens the avatar's eyes when she sees my new duds. Virtual apparel imparts real status. And since many of the people coming here want to meet others, and want to be liked, they're inclined to get more cool stuff that will encourage people to like them (just as in real life). In There, subscribers purchase or create in-game accessories, from hoverboards to self-designed clothes. "I am in There to marvel at the world and the wonderful creativity that talented people are expressing," notes a There veteran named Daemona. In Second Life, the more techie of the two offerings, members can use Linden Lab's scripting tools to build more complicated things—though it takes a certain level of will and design chops to construct, say, your own Tiki hut from scratch.

For virtual worlds to truly evolve into a mass-market communication medium, they need to make money. Whether that will happen remains in doubt. The business model of the moment is subscriptions: inhabiting Second Life costs $10 per month, while residence in There will set you back $5 per month, plus a one-time sign-up fee of $20. Both companies are also making some money through advertising, such as the Nike deal, but ad revenues are tiny. "Advertising adds nothing to our world," says There founder Harvey. Other sources of revenue have begun to appear, though: There, for instance, accepted $3.5 million to develop team-building simulations for the U.S. Army.

More substantial revenues could flow from the player-driven economy. If you run out of Therebucks and don't feel like providing some service in the virtual world, you can simply buy more using your real-world money. There has also built an in-game auction system, similar to eBay, which allows players to exchange goods. In return for this service, sellers must pay There a real transaction fee—in dollars, not Therebucks—that is a percentage of the price of the item being purchased. Linden Lab imposes taxes on its residents; the larger your lot, the more you pay.

Second Life even experienced its very own tax revolt; some of the virtual world's more ambitious builders went so far as to

THE NEW VIRTUAL WORLDS

THERE www.there.com

- **OFFERS:** A neophyte-friendly virtual community with resort-style activities, from hoverboarding to hot tubs
- **BUSINESS MODEL:** A combination of monthly subscription and introductory fees, limited advertising, and transaction fees for user-run auctions

LINDEN LAB www.lindenlab.com

- **OFFERS:** A more geek-oriented virtual playground called Second Life, with do-it-yourself scripting tools that allow you to build elaborate objects within the world
- **BUSINESS MODEL:** A monthly subscription fee, plus a kind of property tax based on the size of your online abode

don colonial garb to protest the high rates. Linden Lab ended up modifying its economic model to address the diehards' concerns.

With a solid technological infrastructure and an emerging virtual economy, these brave new worlds want to go mainstream. But that may take some time. The companies won't say how many subscribers are online at the moment, but tours of There and Second Life reveal that they're modestly populated. In January, There was hit with layoffs that, though explained as a reorganization, have nonetheless raised doubts about its future. According to Schelley Olhava, an analyst with IDC, "The biggest challenge is educating the market. People have to see how much more compelling this is than chat."

And sometimes text-based chat is more than compelling enough. There will always be people who prefer the ease of a quick e-mail or instant message to manipulating an avatar. Often you don't want to hang out; you just want to tell someone to meet you for lunch at noon. "It may be that too few people are interested in this kind of creative expression to build a sustainable business," says Joe Laszlo, senior analyst for the technology research firm Jupiter Research. Also, as IDC's Olhava suggests, There and Second Life have the added challenge of building new brands from scratch. "They don't have the help of an established franchise," she says.

After saying farewell to Lexxa, I seek out an online friend who's been hanging out in There. We find each other by the buggy track and head off for a race. That's the thing about a virtual environment. While conventional chat is basically a bunch of small talk, the "talk" in this world is almost secondary to the experience itself. Who has time to gab when there's rubber to burn? TR

David Kushner is a *Technology Review* contributing writer who covers digital entertainment. He is author of *Masters of Doom: How Two Guys Created an Empire and Transformed Pop Culture.*

Q&A

Michael Moritz

THE HOTTEST VC ON THE PLANET

With Yahoo! behind him and Google's initial public offering rumored to be on its way, Sequoia Capital's Michael Moritz may be the world's preeminent venture capitalist—and he says technology is back.

BY SPENCER REISS PHOTOGRAPHS BY DEBRA MCCLINTON

You'd be smiling, too: If Google goes public, Michael Moritz stands to make hundreds of millions for Sequoia and its clients.

SOMEWHERE RIGHT AROUND the time you're reading this, odds are a headline will be crowing, "Google's $20 Billion IPO Ignites New Internet Boom." Here we go again? From a certain point of view—say, that of young college grads and hopeful entrepreneurs bubbling over with bright ideas—let's hope so.

But if we didn't already know it, what Google's epic launch surely shows is that venture capitalists are the consummate alchemists of the information age. Algorithms bubbling up from a university computer department don't on their own transform into a household verb—much less into a company spewing profits. Increasing the (slim) odds of this happening is where VCs come in—and few do it as well as Michael Moritz.

Moritz is a general partner at Sequoia Capital in Menlo Park, CA, where conference room walls are lined with mementos from three decades of fueling Silicon Valley startups—including infotech icons like Apple, Cisco, and Oracle. Together with another of the valley's VC heroes—John Doerr of Kleiner, Perkins, Caufield, and Byers—Moritz was tapped in June 1999 to join Google's six-member board, which met around a Ping-Pong table. (Between them, the two—often rival—VC firms put up $25 million for an undisclosed share of the upstart search engine company, then still only six months out of a Menlo Park garage.) Doerr's claims to fame included Compaq, Lotus, Netscape, and Amazon.com. Moritz was lower profile, but he had an ace in his hand: four years earlier, he had written a $1 million check to underwrite another quirky Internet "navigation" company with the curious name of Yahoo!

Will Google follow Yahoo! this spring with a spectacular Wall Street debut? Moritz and the rest of the company's Mountain View, CA-based team aren't saying. But the Welsh-born former journalist with a history degree from the University of Oxford and a Wharton MBA was happy to talk with *Technology Review* about the venture business, the perils of startups, and how to turn ideas into billion-dollar markets. I met him at Sequoia Capital's offices off Menlo Park's famous VC warren of Sand Hill Road, overlooking the Stanford University campus.

TR: One happy man who has done Google and Yahoo!: it's almost as if someone did Coke and Pepsi. Is it just dumb luck?

MM: Yes.

TR: Jack Nicklaus used to say, "The more I practice, the luckier I get."

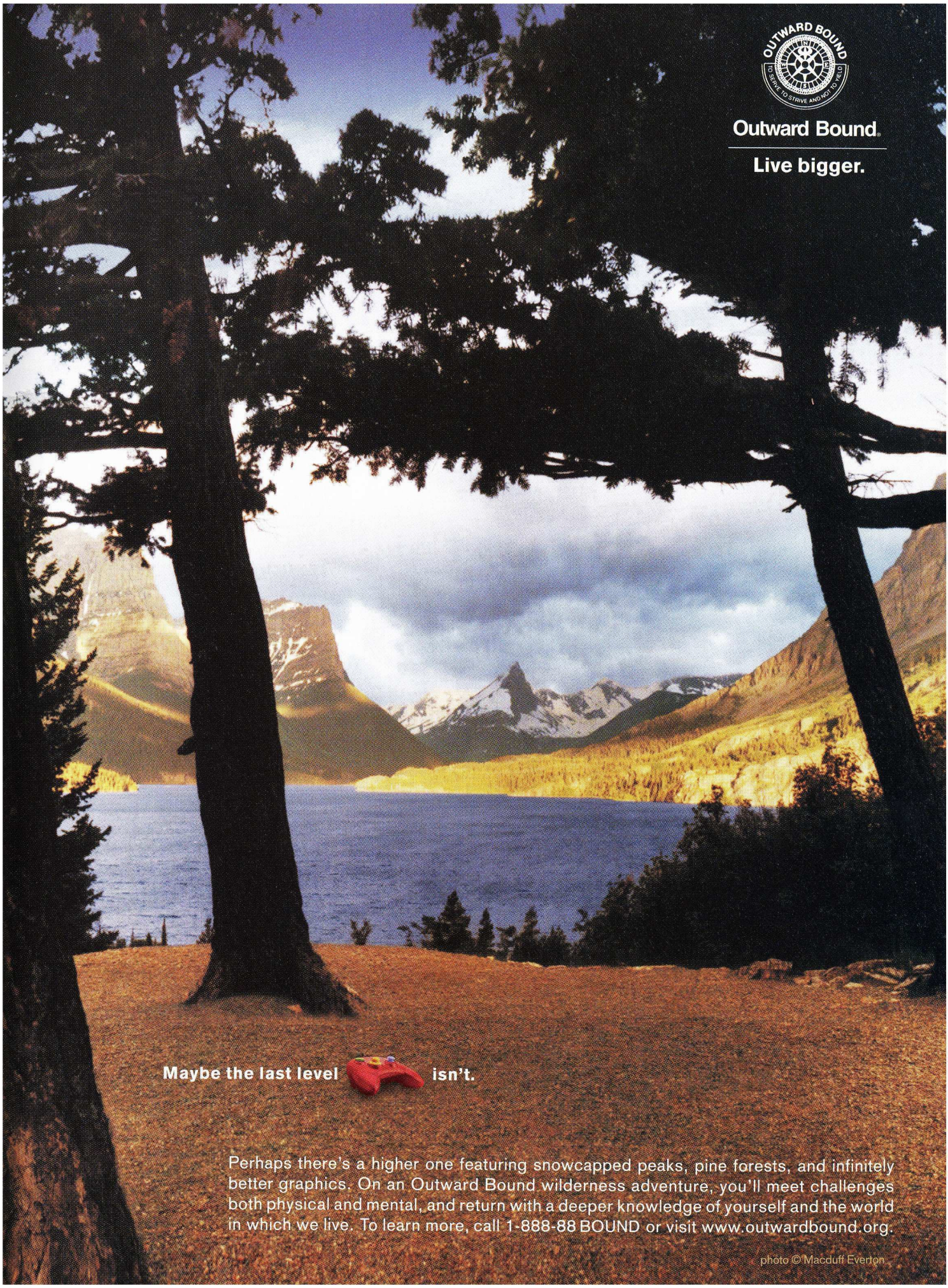
MM: I don't think so. A few years back I was bemoaning the fact that the venture business never seemed to get any easier, and I remember our founding partner here, Don Valentine, saying to me, "Well, why would you expect it to?"

THE MORITZ DOSSIER
Director of **Flextronics » Google » RedEnvelope » Saba Software » AtomShockwave » Plaxo » Pure Digital Technologies » Next Estate**
Founding director of **Agile Software » Global Center**, acquired by Frontier **» LinkExchange**, acquired by Microsoft **» eGroups**, acquired by Yahoo! **» NeoMagic » Quote.com**, acquired by Lycos **» Visigenic**, acquired by Borland **» CenterRun**, acquired by Sun **» Yahoo!**

TR: No learning curve?
MM: You'd think by now we would have figured out a way to avoid making mistakes, and we haven't. The venture business is the ultimate humbling experience.
TR: One thing Google and Yahoo! have in common is being "free" to the user.
MM: Other than Netflix—which ships its subscribers a physical product, movie DVDs—you can't name a subscription-based Internet service that has grown very fast. Obviously, people who use Internet portals are paying the cost of having search results surrounded by advertising. But network television is perceived as being "free," as is radio. The same dynamic—although far more cleverly—is true on the Internet.
TR: Yahoo!'s quarterly profits are up 62 percent. Google's heading toward what could be Silicon Valley's biggest IPO ever. The Dow and Nasdaq are up on the ceiling again. Is it 1999 again?
MM: People are out of hibernation, but we don't necessarily welcome another generation who think they can come to Silicon Valley and make a quick buck. In every cycle there are limos that convey various people with large pretensions around. The same limos—the same drivers, at any rate—will be back, but with different passengers. It really poisons the atmosphere.
TR: What goes into the decision to take a startup company public, and has that changed?
MM: In 1999 it was easier for a company to go public than to fail. That clearly is not the case today.
TR: The result was, a lot of companies went public and then failed.
MM: It will seem peculiar today, but in 1999 it was easier to raise a quarter of a billion dollars than 20 million dollars. So yes, there were some spectacular failures.
TR: So the crash of 2000 had a silver lining?
MM: Clearly. But I've never believed that notion that you can't go public when the stock market is bad. We filed to take PayPal public in September 2001, probably one of the worst months in the last 30 years. There are even some advantages, because the customers aren't used to seeing young, reasonably fast-growing companies. You can get a lot of their attention.
TR: Still, the venture business went into a deep freeze.
MM: Pick whatever verb you want—people evaporated or vaporized or went into hibernation. But there were also a few firms that kept investing, Sequoia among them. We've averaged 15 or 16 investments each year for the last three years. In retrospect, I think the period we've just been through—companies funded in 2001, 2002, 2003—will turn out to be one of the very best venture periods of all time. You're able to do more with a lot less.
TR: In a downturn?
MM: People should understand that in any five-year period, Silicon Valley is capable of producing only a handful of very distinctive companies. It's unrealistic to expect this little portion of the universe to generate 35 great companies a year.
TR: Let's look at some currently hot sectors. Voice over IP?
MM: It's one of those currents that should only get stronger.
TR: Any worries about startups being swamped by the big boats?
MM: We tend to be optimistic about that, and it doesn't matter whether we're dealing with components or systems or software. There's always a big company lurking somewhere.
TR: How about spam—or maybe we should say, anti-spam?
MM: I think we can count on the infinite creativity of nefarious characters around the world to keep this lively. It's like the antivirus market: everybody thought that would go away in the late 1980s, and obviously it's been an enduring business. We have investments in a couple of companies, including Corvigo; it does a filtering appliance for enterprises.
TR: Authentication, online identity?
MM: Again, there are a lot of big companies lurking around, and one of the questions a little company has to solve is how to become a trusted entity. We have one company in particular that's working on that, but we haven't even talked about it yet. It's early days. There are a lot of big players out there who want to own this.
TR: Speaking of big players, Bill Gates is very keen on Web services. A lot of people still don't understand what that means.
MM: Well, join us: we don't understand it either. It used to be everybody was supposed to have an artificial-intelligence investment. Right now you're supposed to have Web services in your quiver.
TR: But what is it?
MM: At the moment, it seems to be anything you want it to be. But there are certainly companies that will make their living based on the coming trend toward XML [Extensible Markup Language, a protocol for organizing data on the Web]. That sounds very bland—"doing real things for the customers." The good news might be that I haven't heard the phrase "Web services" for some time now. I think it's last year's wallpaper.
TR: How about security?
MM: Absolutely, in all shapes and forms. For us, it's security in the enterprise; it's security around wireless devices; it's securing major Web sites. We have an investment in a public company called Netscreen, and also in some private companies, Netscaler and RiverHead. It's a very complicated area, and again, it looks as if it's going to be one of these things that will be with us for a long time.
TR: One more: "social networking"—the whole Friendster craze. Maybe we're missing something, but it's hard to see people swapping friends the same way they swap DVDs on eBay.
MM: Community areas—if they do something real for the community—have been good places to invest. We were happy investors years ago in LinkExchange and eGroups. But all of these companies have to build businesses, and none of them have yet shown that they can do that. We're invested in a company called LinkedIn, which is focused on the professional marketplace.

TR: Could you give a hint about where you're looking for ideas?
MM: I never answer that. It's like expecting a product company to announce its future products.
TR: Sequoia's Web site says you look for "the marriage of extraordinary passion with an enormous market potential, preferably billion-dollar-plus." That's a pretty high bar.
MM: Internet advertising was a zero-million-dollar advertising market in 1995. Last year it was probably $12 billion. Outsourcing manufacturing services is a hundred-billion-dollar business that didn't exist in the mid-'80s. The trend you latch on to may only be a $50 million marketplace today, or it may not even exist. But you've got to feel convinced that the dynamics are there so that it can blossom. Otherwise it's just not worth the effort.
TR: It also says you "prefer a simple product with lots of prospective customers over patent-protected devices." Not exactly encouraging words for someone in a top university lab.
MM: That's a bit of hyperbole. Obviously, if you can have a product that you can sell to lots of people that you can have technology barriers around, that's a wonderful thing. But lots and lots of customers probably afford your business better protection than a few patents.
TR: Do you see any shifts in the relative importance of what we'll call "pure" technology ideas—an innovative bit of hardware or a software application—and the more services-oriented plays?
MM: Not really. Advances at the component level still fuel everything that happens further down the food chain.
TR: Can you see a time when the Internet ceases to be a "technology" area and becomes just another business? Once upon a time, light bulbs and automobiles were the bleeding edge.
MM: For the better companies, making headway on the Internet has always been a business.
TR: We don't hear much these days about "Internet time." Is that still a valid idea?
MM: The only time that matters is time to market.
TR: How about "first to market"?
MM: An utterly dreadful phrase. I way prefer to focus on how a company becomes first *in* market.
TR: And "passion"? You've cited Steve Jobs and Steve Wozniak at Apple and David Filo and Jerry Yang at Yahoo! as examples of entrepreneurial drive. But the same could be said about the founders of eToys and Webvan, and look how they turned out!
MM: People who haven't worked at a small company don't understand how difficult it is to get one off the ground, and the amount of drive and tenacity and enthusiasm—passion, in other words—you need in order to build the business out of nothing. Yes, some of them go awry; many of them disappoint.
TR: Was the problem in the late '90s just too much money?
MM: It certainly flew in the face of everything that we try to preach, about how the best venture capital returns actually come from companies that don't take a lot of capital to get off the ground and that get profitable fairly early.
TR: What's the worst company you've ever put money into?
MM: We fail a lot and make tons of mistakes. But clearly the worst investment we ever made—not the worst company, by the way—was Webvan. It was a 16-wheeler nightmare. I feel a migraine coming on as soon as I think about it.
TR: You've had companies where the founders tried to kill each other…
MM: The little companies we invest in are stacked with all sorts of human drama. Some of the soap operas would just stun you. We did indeed have a company where one cofounder drove a pickup truck through a plate glass window in an effort to exterminate another. It was a more dramatic example of the gulfs that sometimes occur between management teams or cofounders.
TR: Midnight phone calls?
MM: The dreadful news travels a lot more quickly than the good news. We had a call just this morning—a new CEO frantically announcing that a creditor had swept all the cash out of their bank account. That was eight hours ago.
TR: You've done investments in less than 24 hours.
MM: Frequently they're ones we come to regret.
TR: Are there things you won't even look at?
MM: You'll think I'm kidding, but again, I got an e-mail this morning about some guy who wanted to know whether we'd consider investing in pig farms in Russia. A little bit beyond the ken, but we will look at every business plan; we'll look at every e-mail for the sectors we work in.
TR: What's the best idea Sequoia Capital has turned down?
MM: Silicon Graphics. And more recently, Netflix. It came along during a period when we didn't have enough time to think—there was such a hurricane of new ideas every day.
TR: Best idea that you wish you'd had a chance to turn down?
MM: Expedia, but Mr. Gates owned that one.
TR: Entrepreneurs are often associated with risk taking. What's the risk-taking weather report? Did people go into hibernation again on risk taking for the last couple of years?
MM: Yes, they certainly did, although you could look at it the other way: the people that you really want to be in business with are the people who have the fortitude to want to try and start a business precisely at the time that everybody else doesn't.
TR: Do you see the PC's status diminishing?
MM: Potentially, but I think computing in general will play an ever bigger part of everyone's life. I remember 25 years ago listening to Gordon Moore telling about all these computers that would be in cars, refrigerators, and everything else. Well, I just sold one car that had too many computers—they all kept going wrong.
TR: Outsourcing: are you worried that "jobs moving overseas" will undermine support for free trade, with calamitous effects on the world economy?
MM: Outsourcing will have calamitous effects on all the people who are in denial about it. We have investments in a company called 24/7 Customer that operates call centers in India. It makes the companies here that use its services much stronger companies.
TR: The Internet: over- or underhyped?
MM: I'd say underused compared to where it will be. We don't spend a lot of time here thinking about the economy or talking about the information economy or the industrial economy. We just want to invest in a business or a company—to be the entrepreneurs behind the entrepreneurs. I know that sounds simplistic, but it's the reality of what we do.
TR: Last chance for a lesson from your amazing run of "luck" launching Internet companies?
MM: Small amounts of money, tight groups of very focused people, an unwillingness to splurge when temptation calls, constrained infrastructure, outsourcing all that is unessential. In other words, less makes more.

Spencer Reiss specializes in interviewing people smarter than he is.


OUTWARD BOUND
TO SERVE TO STRIVE AND NOT TO YIELD
Outward Bound.
Live bigger.
Maybe the last level
isn't.
Perhaps there's a higher one featuring snowcapped peaks, pine forests, and infinitely better graphics. On an Outward Bound wilderness adventure, you'll meet challenges both physical and mental, and return with a deeper knowledge of yourself and the world in which we live. To learn more, call 1-888-88 BOUND or visit www.outwardbound.org.
photo © Macduff Everton

sweet hope

for a malaria vaccine

Malaria remains one of the world's most deadly diseases, with devastating economic effects in developing countries. In the search for the first vaccine against this killer, a band of researchers and a tiny startup have turned to an unusual new weapon: a sugar.

BY ERIKA JONIETZ
PHOTO BY IAN BERRY/MAGNUM

Looking up: A doctor checks the condition of malaria patients in Burundi, Africa.

EACH YEAR, MALARIA PARASITES INFECT up to half a billion people and kill at least one million, most of them in sub-Saharan Africa, most of them children under the age of five. Nearly 3,000 children die each day. Before dying, they suffer severe anemia and recurring bouts of high fever, as the microbes invade red blood cells, reproduce, and escape, exploding the cells and releasing a devastating toxin. Fluid accumulates in the lungs, the blood turns acidic, the kidneys fail, and the brain can become inflamed, causing dizziness, seizures, and even personality changes.

And that doesn't even fully describe the horror of the disease. "It's not just the deaths," says Filip Dubovsky, the scientific director of the Malaria Vaccine Initiative, a program funded by the Bill and Melinda Gates Foundation. "It's the farmer who's too sick to get to his work, to feed his family. It's the loss of a fetus to a mother who's expecting a baby. The thing is, people are used to it—and that's one of the biggest tragedies."

For decades, public-health groups have combatted malaria by trying to control infective-mosquito populations with insecticides and treating as many of the ill as possible with antimalarial drugs. But problems with parasite resistance to the drugs and mosquito resistance to the poisons—not to mention distribution costs and logistics—mean that far too often these strategies fail. Essential to the battle is finding a way to prevent the disease despite infective bites. "A vaccine is really badly needed," says Marcel Tanner, director of the Swiss Tropical Institute in Basel. An effective vaccine could be cheaply and easily integrated into existing programs to immunize infants in malaria-infested regions against common childhood diseases. And in fact, researchers are working on almost 90 different versions of a malaria vaccine, 17 of which have started human testing *(see "Sampling of Malaria Vaccines in Human Testing," p. 68)*.

MALARIA KILLS 3,000 CHILDREN DAILY—MOST UNDER THE AGE OF FIVE.

Despite decades of effort, however, scientists have yet to produce a vaccine that works. "There has been a lot of technical failure," says Marie-Paule Kieny, who coordinates the World Health Organization's funding of malaria vaccine research. The main reason is that the parasites make slippery targets, routinely changing their appearance as they mature and spending much of their lives inside human blood cells, where the immune system has a hard time tracking them down. Since most vaccines work by training the immune system to fight invaders directly, the malaria microbes' exceptional elusiveness has made vaccine development maddeningly frustrating.

But new hope is emerging from an unlikely source: the sugar responsible for the disease's devastation. Instead of prompting the immune system to find and kill the malaria parasites, a new vaccine seeks to prime the immune system to attack the toxin that causes the most lethal aspects of the disease. The result of a collaboration between immunologist Louis Schofield of the Walter and Eliza Hall Institute of Medical Research in Melbourne, Australia, and chemist Peter Seeberger of the Swiss Federal Institute of Technology in Zürich, the vaccine consists of a synthetic version of the malaria toxin—a sugar molecule that Schofield first identified in the late 1980s. So far, tests of the vaccine have yielded promising results in animals.

To commercialize the vaccine, Seeberger and Schofield have helped start up a company, Ancora Pharmaceuticals in Cambridge, MA. With the right funding, Seeberger says, the team could be ready to start human tests by the end of the year; but that funding has yet to materialize. The problem is in many ways endemic to malaria research. And the cause is simple: the disease afflicts mainly poor countries that have little political or financial clout. "One of the toughest things with malaria is going to be getting a way to finance the work," says biotech entrepreneur Carmichael Roberts, Ancora's cofounder. Seeberger is blunter. "Hell would break loose if 40,000 people died in the U.S. in a month," he says, as has happened in some malaria-ridden regions of Africa.

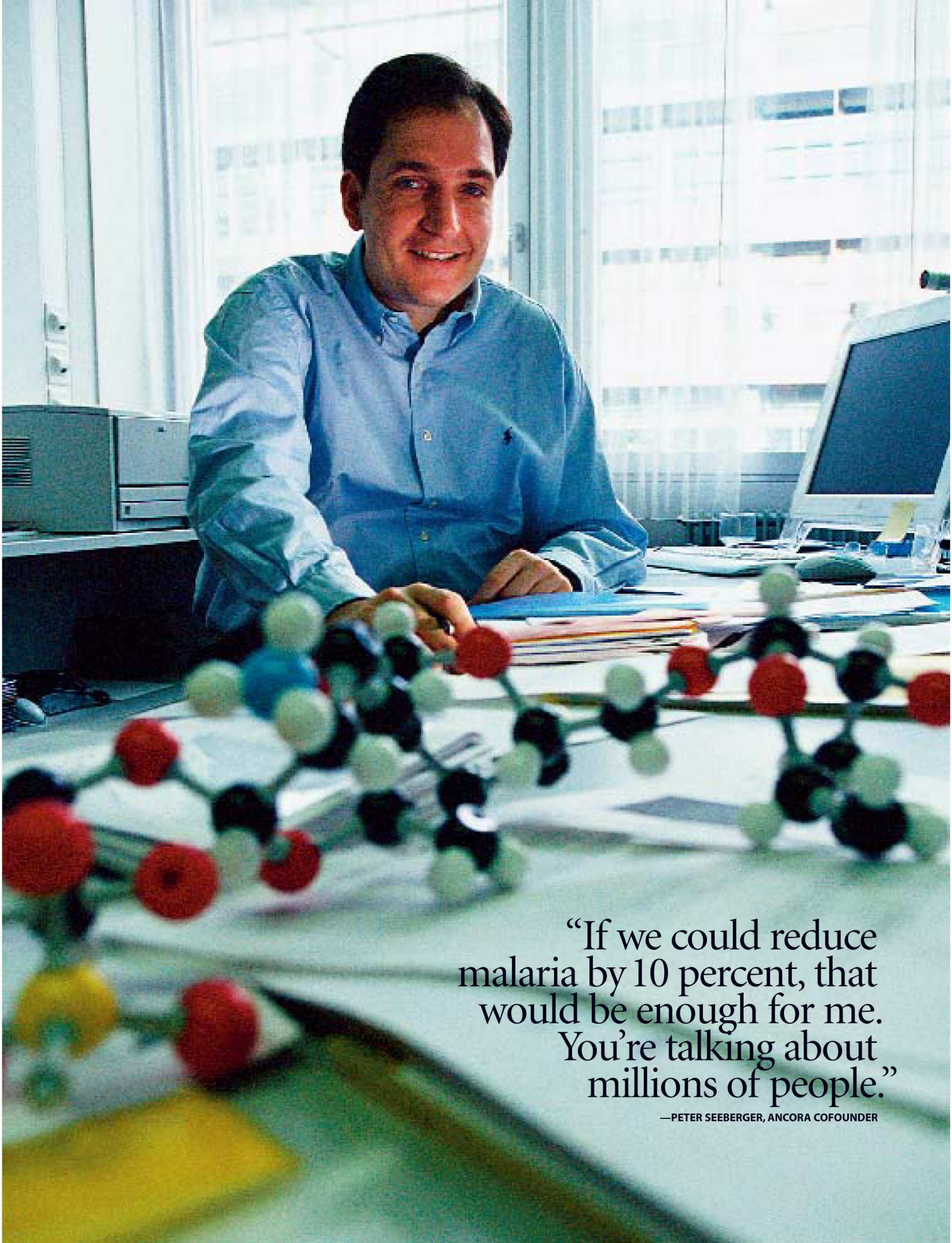
Many experts doubt that the sugar-based vaccine will be the sole answer to malaria, but if it works, it could be a vital piece of the strategy for combatting the disease. Because the vaccine comprises a sugar, it has advantages over other vaccines being tested: it does not require refrigeration, and it could be more robust against parasite resistance. And that could help it save lives and ultimately boost the economies in many developing nations. "If we could reduce malaria by 10 percent, that would be enough for me," Seeberger says. "You're talking about millions of people."

TARGET: TOXIN

You can excuse Louis Schofield's impatience to begin human testing. His search for an effective malaria vaccine is now in its third decade. His quest began in the late 1980s, when as a postdoc at New York University, he went hunting for the malaria toxin. His idea, even then, was that vaccinating against the toxin rather than the parasites could prevent the actual disease—the fever and uncontrolled inflammation that are the deadly hallmarks of malaria. Unlike the parasites, Schofield reasoned, the toxin exists outside the blood cells and should be readily accessible to the immune system.

In general, vaccines work by inciting the immune system to produce proteins called antibodies; each antibody specifically reacts with one particular molecule—say, a protein on the surface of a parasite. This interaction typically focuses the killing effects of the immune system on the invader. But the antibodies recruited by an antitoxin vaccine like the one Schofield has in mind simply bind to the toxin, neutralizing it. The concept is not unique: two of the world's most successful vaccines, against diphtheria and tetanus, are such antitoxin vaccines.

But to create an antitoxin vaccine, you first have to find the toxin. Much of malaria research has focused on proteins, but Schofield took a different tack, going after a suspicious mole-



"If we could reduce malaria by 10 percent, that would be enough for me. You're talking about millions of people."

—PETER SEEBERGER, ANCORA COFOUNDER

OTHER SUGAR VACCINES

DISEASE: Breast cancer
PREVALENCE: More than 200,000 new cases of invasive breast cancer are diagnosed annually in the United States; almost 40,000 women die each year
WHY CARBOHYDRATES: Cancerous cells produce more of certain sugar structures than healthy cells; vaccines targeted to these sugars teach the immune system to attack cancerous cells the same way it would foreign bacteria
STATUS: A synthetic vaccine is being tested on breast cancer patients: phase I trials complete; phase II/III trials planned
LABS: Samuel Danishefsky, Columbia University and Memorial Sloan-Kettering Cancer Center (New York, NY), with Optimer Pharmaceuticals (San Diego, CA)

DISEASE: Tuberculosis
PREVALENCE: Sickens about eight million people each year and kills two million, making it the single most lethal infectious disease
WHY CARBOHYDRATES: The cell walls of TB bacteria are rich with sugar molecules; a sugar vaccine could stimulate the immune system to fight TB
STATUS: Preclinical research is being done on the TB bacterium
LABS: Patrick Brennan, Colorado State University (Fort Collins, CO); Ancora Pharmaceuticals (Cambridge, MA)

DISEASE: Streptococcus B. Usually harmless, in newborns the bacterium can cause bloodstream disease and pneumonia, and may even cause meningitis in extreme cases
PREVALENCE: One in 1,000 U.S. newborns; of these, one in 20 dies
WHY CARBOHYDRATES: A thick sugar coat covers the outside of the bacterium; a sugar vaccine primes the immune system to attack the bacterium
STATUS: Purified natural sugars are being tested as a vaccine in healthy adults and pregnant women
LABS: Dennis Kasper, Harvard Medical School (Boston, MA); Carol J. Baker, Baylor College of Medicine (Houston, TX)

DISEASE: Leishmaniasis. The *Leishmania* parasite is transmitted by sand flies and causes disfiguring skin sores, anemia, fever, and swelling of the liver and spleen
PREVALENCE: Infects 12 million globally; becoming a problem for U.S. soldiers in the Middle East
WHY CARBOHYDRATES: Sugar molecules coat the surface of the parasite; a sugar vaccine could stimulate immunity
STATUS: Preliminary animal tests have shown positive results
LABS: Sam Turco, University of Kentucky (Lexington, KY); Mike Ferguson, University of Dundee (Scotland)

cule, a carbohydrate studded with fats, found on the parasite's cell surface. He thought that this molecule could be the villain causing the inflammation problems characteristic of malaria. "That turned out to be a good guess," he says. Over 18 months, at the National Institute for Medical Research in London, he painstakingly extracted the toxin from malaria parasites. Once he had enough of it in hand, he injected it into mice; the rodents grew sick, experiencing a slew of symptoms—"pretty much those that you see in people sick and dying of malaria," he recalls. He had found the malaria toxin.

But a tremendous hurdle still remained. Without a way to make a completely pure version of the toxin's carbohydrate backbone—and do it relatively quickly—Schofield could not prove it would make an effective vaccine, much less produce it commercially.

The technological breakthrough came several years later from research being done in Cambridge, MA. Then at MIT, chemist Seeberger, working with graduate student Obadiah Plante, had invented a machine that automated the laborious and time-consuming synthesis of sugars. Seeberger's machine tantalized Schofield: it could churn out large quantities of a pure version of the basis for a vaccine cheaply and quickly, possibly within weeks or days.

Optimistic and determined, Seeberger took on the project—and a partnership was born. "He undertook to do the synthesis on the strength of my conviction," Schofield says. Seeberger first made a stripped-down version of the toxin. Though the process initially took 10 months, he soon had it down to a matter of hours. Then, in Schofield's lab, researchers infected mice with malaria parasites. Normally, almost all of the animals would have died within a week. But injection with a prototype vaccine based on Seeberger's molecule apparently negated the effects of the toxin, raising the rodents' survival rate to between 65 and 75 percent. "The results were very clear," Seeberger says.

ANCORA'S ANSWER

Based on these results, Seeberger and Schofield decided to make malaria an early target for the type of sugar-based vaccines and drug treatments they planned to develop at their new company, Ancora Pharmaceuticals. On a recent visit to Ancora's lab in Beverly, MA, Seeberger—who flies in from Switzerland every four to six weeks—showed off the technology that he hopes will help make the malaria vaccine a reality.

Tucked into a corner of a large, nondescript office park, Ancora sublets its space from another startup: one long, narrow room that serves as an office area and a couple of work counters in a lab. It could be any other fledgling company short on money—except for the pair of boxy, automated sugar synthesizers that sit sequestered behind a closed door. While not quite the heart and soul of the tiny firm—those would be its founders—you might call these machines the company's backbone.

Crowded into the office with three of Ancora's four full-time employees, Seeberger explains the significance of the synthesizers. Sugars play a number of important roles in the body, including mediating interactions between invading microbes and the immune system. And sugars are remarkably complex. Before Seeberger's invention, researchers took months or even years to make a particular sugar molecule.

LESTER LEFKOWITZ/CORBIS

The automated synthesizers have changed all that. Each occupies a large countertop and holds banks of small glass bottles that contain specially designed carbohydrate building blocks and other chemicals needed in sugar-producing reactions. Run by a computer, the machines automatically pipe the building blocks into a reaction vial in the proper order and with the right timing. The final result: perfectly synthesized sugar molecules.

An effective malaria vaccine is not the company's only focus. "Throughout infectious disease, there are opportunities for carbohydrates," says Seeberger. "It's a matter of picking the diseases and focusing on the right sugars." One potential candidate is tuberculosis. The only available vaccine is hardly effective: it has been estimated to prevent only 5 percent of potentially vaccine-preventable tuberculosis deaths. And scientifically, it turns out to be a short hop for Ancora. "For malaria and TB, the building blocks are not so different," Seeberger says. Nor does the hope for carbohydrate-based vaccines end there; labs around the world are testing carbohydrate molecules—some natural and some synthetic—as vaccines against several other parasites and bacteria, and even against cancer *(see "Other Sugar Vaccines," p. 66)*.

With the basic technology in place, Ancora's biggest challenge in developing and testing a malaria vaccine is funding. The company is bootstrapping the project for now, with money from angel investors and U.S. government grants. A grant from the National Institutes of Health has allowed the researchers to begin scaling up production of the malaria sugar to amounts that could be used in human tests of the vaccine. Funds for vaccine test trials, however, have yet to turn up, says Seeberger.

MALARIA CLAIMS 90 PERCENT OF ITS VICTIMS IN SUB-SAHARAN AFRICA.

WAITING GAME

Coming up with a new malaria vaccine is a risky business—and plenty of researchers are skeptical about Ancora's novel approach. While Schofield's mice survive, immunized against the toxin, they still have high parasite levels in their blood. Experts voice concerns that those microbes might eventually cause trouble on their own. "The question is, at what point would [the mice] just continue to go on and develop complications," becoming sick from uncontrolled parasite growth despite the neutralization of the toxin, says Lee Hall, chief of malaria vaccine development at the National Institute of Allergy and Infectious Diseases in Bethesda, MD. Still, Hall explains that the sugar-based vaccine could be useful—especially if used in combination with antiparasite vaccines.

Schofield, however, believes that his vaccine can stand on its own. "I think toxin is bad for you; parasite doesn't matter too much—provided the toxin is taken care of," he says. Studies in Papua New Guinea, for instance, have shown that inhabitants can carry high parasite burdens in their blood but exhibit no disease. "I've seen it," Schofield says. "You see kids in the first year of school playing football in recess, attending class—you do a survey on them, and some of them have got pretty high parasite levels. If you saw that in you or me, we'd be at death's door." Schofield suspects that these children may, in fact, be immune to the toxin, but not to the parasite.

In theory at least, a synthetic-sugar-based vaccine has numerous advantages over protein vaccines. A synthetic vaccine is easier to manufacture to strict pharmaceutical standards than one produced biologically, as protein-based vaccines are; this should make it easier to meet safety requirements. Sugars are also more stable than proteins, which would make a sugar-based vaccine easier to store and distribute, especially in Africa, where the refrigeration required for proteins is scarce. And a sugar-based vaccine might be less susceptible to parasite resistance than a protein-based one.

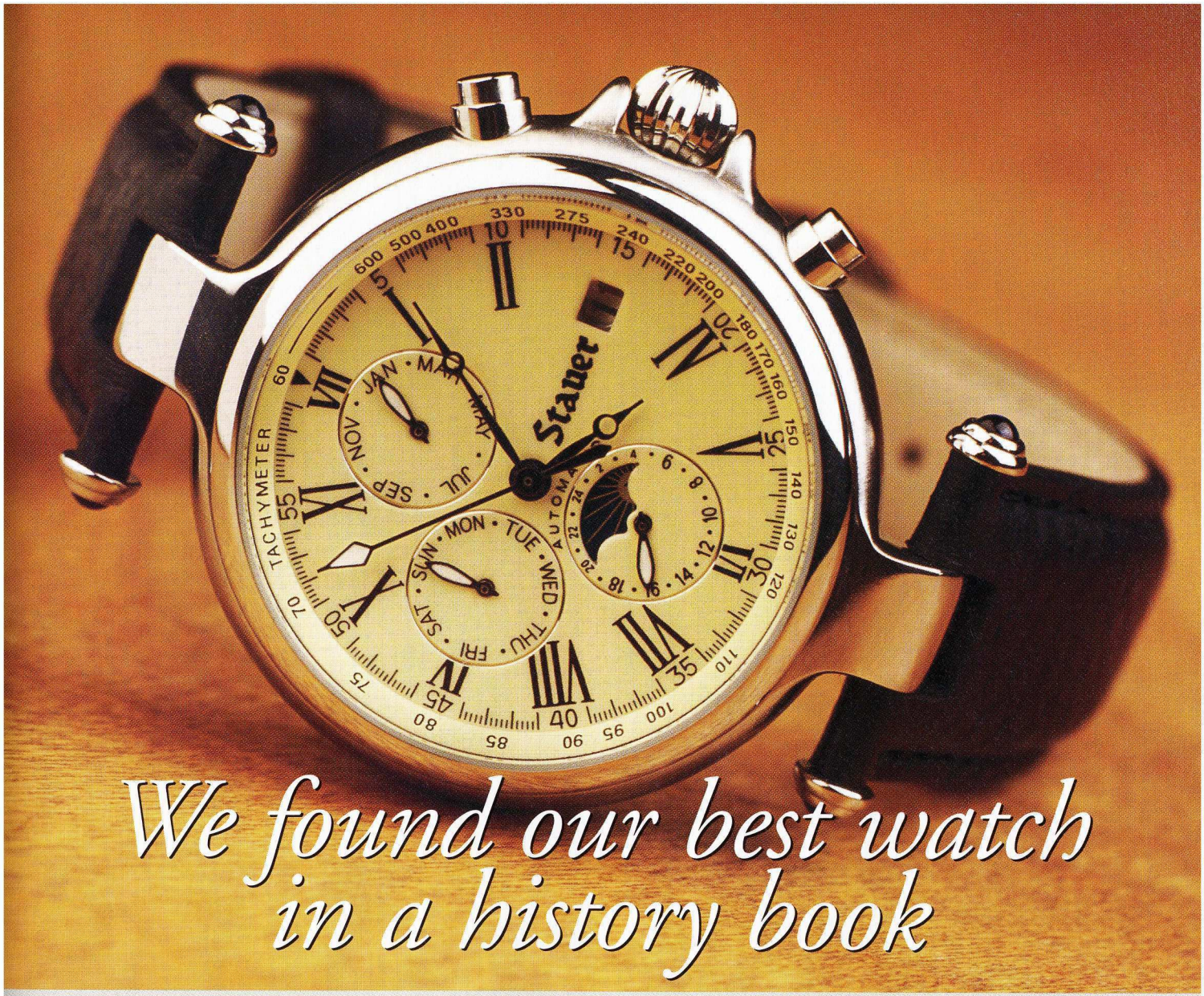
Of course, no one can really know how effective Schofield's vaccine will be until it is fully tested in humans. But if he and his collaborators prove right, and if all this theory translates into a widely distributed vaccine, entire regions of Africa and Southeast Asia could be transformed: tens of millions would never become sick, and hundreds of thousands would not die from malaria. Whole economies could be rejuvenated. "All I want to do is to see this tested in humans," Schofield says. "I don't think there's anything wrong with skepticism—it's easy to make grandiose claims. The only thing I regret is that at the moment, we need the resources to be able to test this properly."

If that doesn't happen, the real losers in the waiting game won't be Schofield or Seeberger or Ancora, but the millions of men, women, and children sick and dying each year, caught in malaria's cycle of tragedy.

Erika Jonietz is a *Technology Review* contributing editor based in Houston, TX.

SAMPLING OF MALARIA VACCINES IN HUMAN TESTING

GROUPS	VACCINE/STATUS
GlaxoSmithKline Biologicals (Rixensart, Belgium)	Protein vaccines; the most advanced is in phase II clinical trials in children in Africa
Queensland Institute of Medical Research (Brisbane, Australia); **Cooperative Research Centre for Vaccine Technology** (Brisbane, Australia)	Protein vaccine; phase I trials
University of Oxford (Oxford, England); **Oxxon Pharmaccines** (Oxford, England); **Impfstoffwerk Dessau-Tornau** (Rosslau and Dessau, Germany)	DNA vaccine; phase II clinical trials in Africa
Walter Reed Army Institute of Research (Forest Glen, MD)	Protein vaccines; the most advanced is in phase II trials in Africa



We found our best watch in a history book

In 1922, a small watchmaker in Switzerland patented the first automatic watch to display the day, month and date. Only 7 of these magnificent timepieces were ever made and this watch was almost lost to history. Today, they are so rare that one original chronograph watch would probably fetch more than $300,000 at auction.

These watches were among the most stylish of the roaring 20's. And yet no one has attempted to remake this 1922 classic until now. The Stauer watch design that you see here has been painstakingly recreated from the original functions to please even the most discerning owner. The owner of this classic chronograph watch is sure to look distinguished and set apart from the crowd. From the sweeping second hand to the Roman numerals on the unique ivory-colored face, every detail has been carefully reproduced. This Stauer reissue is a limited series, allowing you to wear a watch far more exclusive than many Rolex, Movado, TAG Heuer or Breitling watches.

The watch has a 21-jewel mechanical movement, the kind desired by fine watch collectors. We have updated this movement with kinetic power thus the watch never needs to be manually wound. The watch comes in a beautiful case and comes with both interchangeable black and brown leather bands.

This is a chance to claim a piece of watchmaking history in an elegant design that is still priced to wear every day. This offer is being made directly to you so you can add this watch to your collection at a very affordable price. The watch comes with a 30-day no questions asked money-back guarantee. If you're not completely satisfied, simply return it for a full refund of the purchase price.

Not Available in Stores

Call now to take advantage of this limited offer.

Stauer 1922

3 Easy Payments of $49+S&H.

800-859-6584

Promotional Code SNN287-04

Please mention this when you call.

To order by mail, please call for details.

NEXTTEN

products for your next ten years.

14101 Southcross Drive W., Dept. SNN287-04
Burnsville, Minnesota 55337

For fastest service, call toll-free 24 hours a day **800-859-6584**

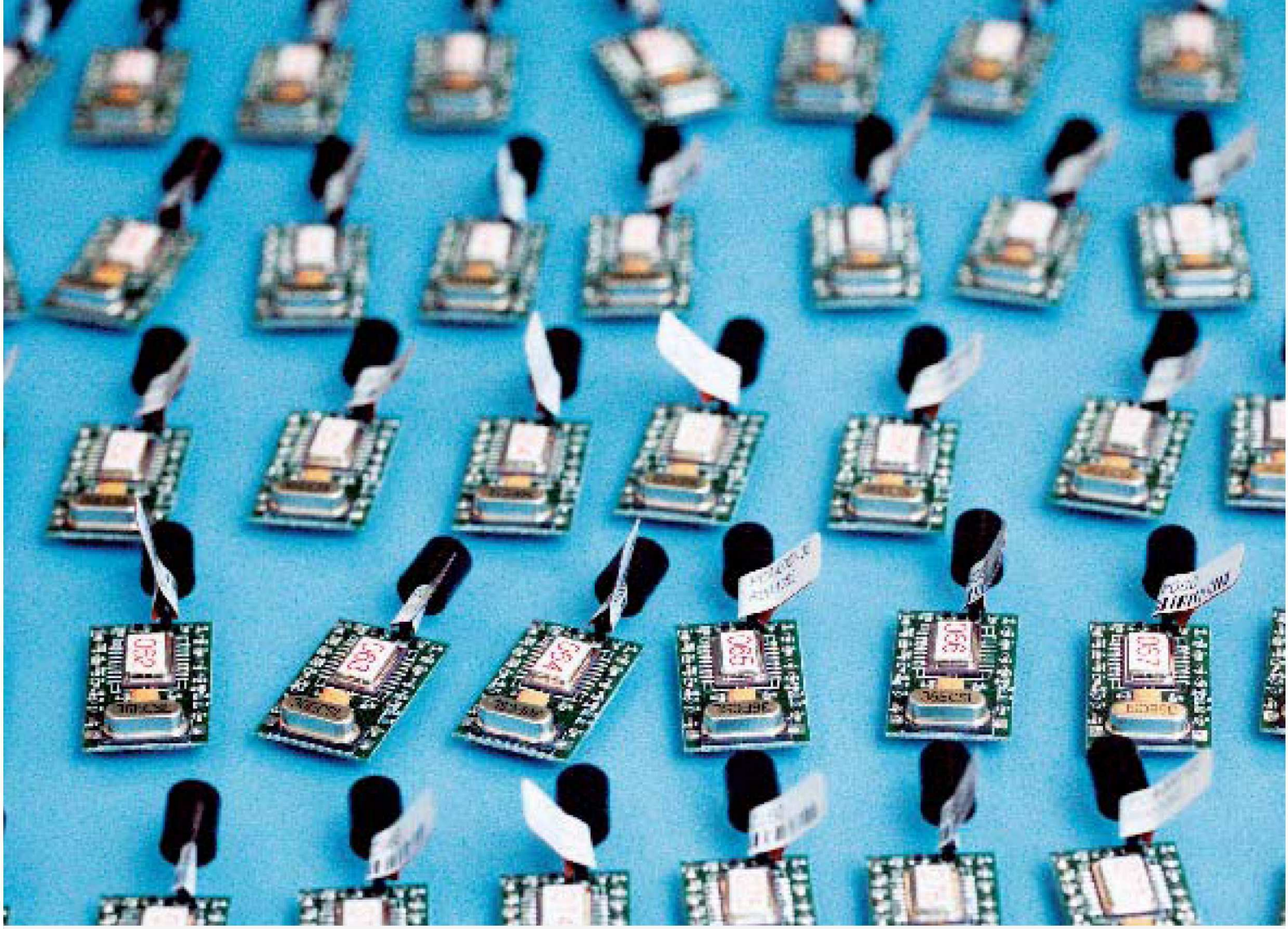
Visit us online at www.NextTen.com for the complete line of Stauer Watches, Jewelry and Collectibles

DEMO

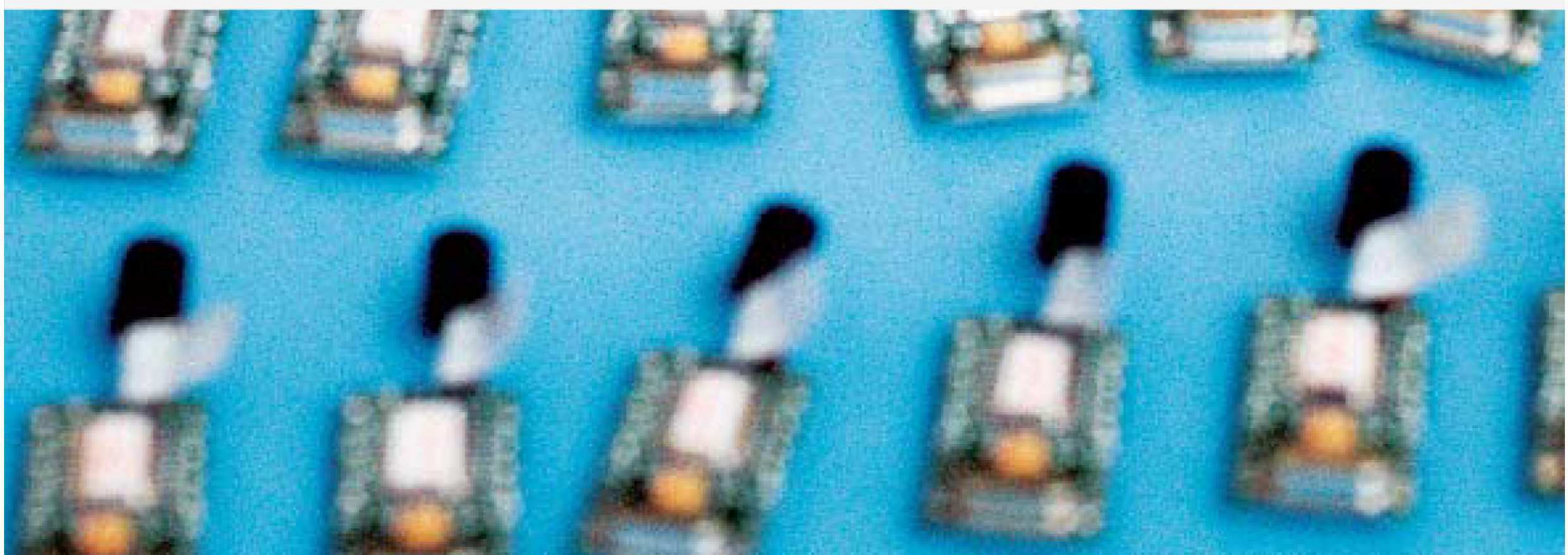
SENSOR WORLD

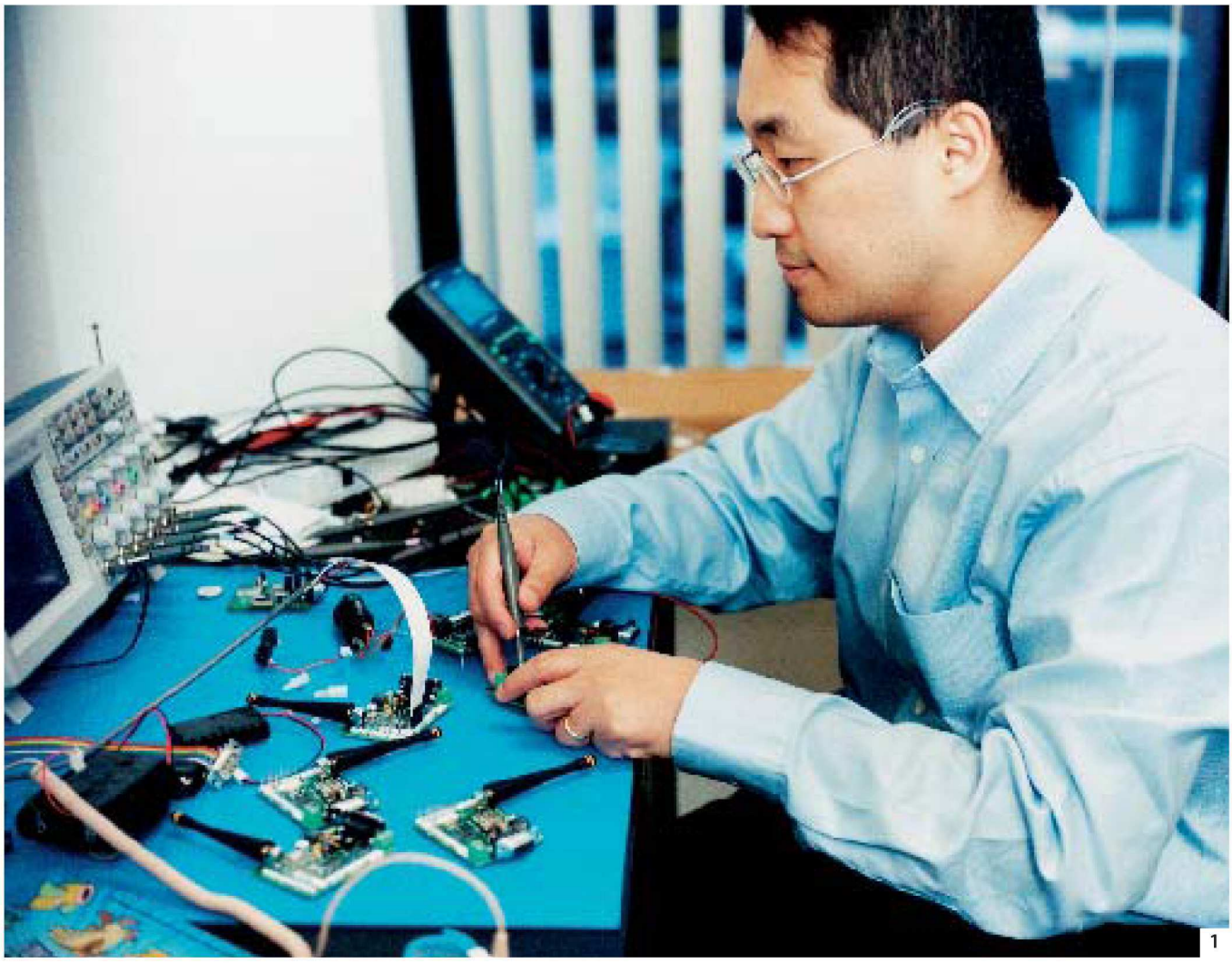
IMAGINE A WORLD IN WHICH TINY WIRELESS SENSORS REPORT BACK TO YOU ON EVERYTHING FROM AIR QUALITY TO TEMPERATURE CHANGES TO TRAFFIC CONDITIONS. **SOKWOO RHEE** AT **MILLENNIAL NET** IS BRINGING IT CLOSER.

PHOTOGRAPHS BY KATHLEEN DOOHER



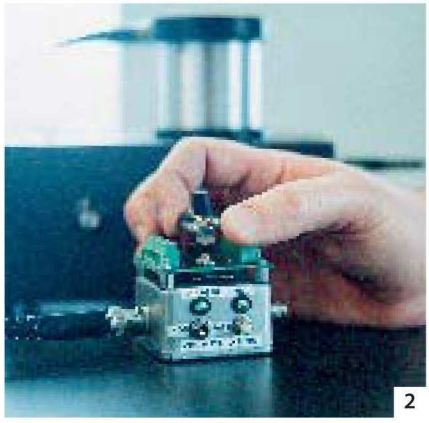
EMBEDDED IN HOMES, OFFICES, CARS, AND FACTORIES, thousands of tiny computerized sentries could track inventories, monitor electricity use, and even detect ground vibrations and toxic gases to provide early warning of earthquakes and chemical spills. But how are researchers turning this vision into reality? "What we bring to the table is, we make real products," says Sokwoo Rhee, chief technology officer of Millennial Net, an MIT spinoff. By designing ultralow-power, postage-stamp-size hardware and smart networking software for sensors, he says, his team is building the "Swiss Army knife of wireless applications" that can go anywhere, anytime. Millennial Net's products are already being used to automate and report meter readings, detect carbon monoxide and turn on ventilation fans in parking garages, and track temperature-sensitive items like food and drink in transport. The goal is to be integrated into "millions of devices by 2007," says Rhee, so that a sensor in a streetlight, say, could alert you to weather or traffic problems via your cell phone. At Millennial Net's headquarters in Cambridge, MA, Rhee showed *TR* associate editor Gregory T. Huang how to assemble a wireless mesh of networked sensors—and deploy them to do work in the real world.



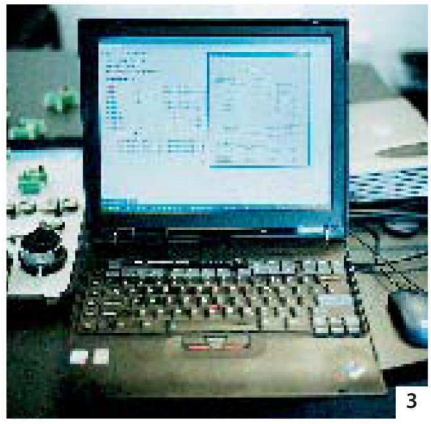


1. NODE NEWS IS GOOD NEWS. Say you want to set up a wireless sensor network to closely monitor temperatures and energy use at many spots in a large office building. The first step is to gather network "nodes," which are connected to different kinds of sensors and communicate wirelessly with one another.

In his office, Rhee tests out some newly minted nodes. Each node has a processor, memory, a radio, and a battery and is programmed to store data and talk to other nodes. Rhee probes each piece of hardware, checking the strength and timing of various electrical signals. "We look at the network behavior to see how the nodes interact with each other," he says. The nodes must be able to organize themselves into a usable network and adapt to other nodes' getting turned on or off or moved around.



2. POWER PLAY. Key to a practical sensor network is power consumption: nodes may need to work for years without access to fresh batteries. Rhee's nodes need so little power that they could run on vibrations from the environment—say, a rattling heating duct or a bumpy truck ride. To test this approach, Rhee places a cylindrical "energy harvester" on top of a vibrating platform. The harvester converts the vibrations into electricity to power a sensor node *(in hand)*. This project is early-stage, says Rhee, but eventually his nodes could be completely battery free.



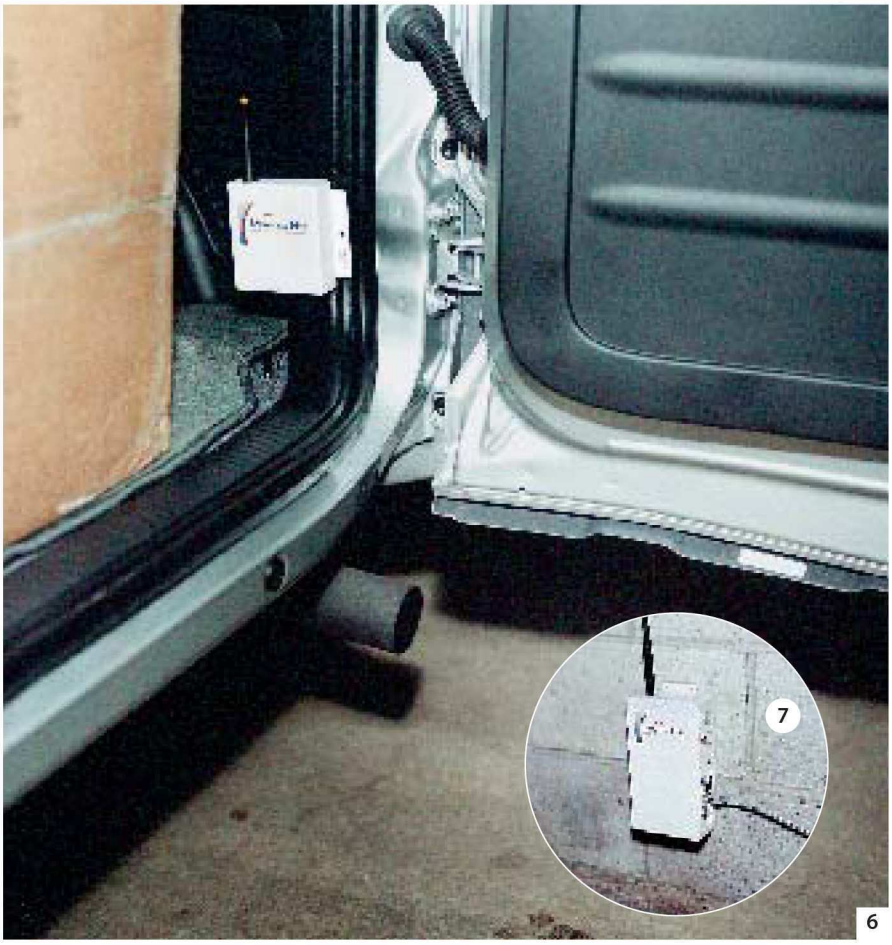
3. NETWORK GOES LIVE. Next, Rhee gets his state-of-the-art sensor network up and running. To make sure things are working, he spreads nodes around the lab. One by one, they come online, taking temperature readings and routing data to each other. One node connects to a laptop, which shows the status of all nodes—who's talking to whom and when—and lets the user click around to get more info. This could also be done via a handheld computer.

4

5

4-5. SENSORS THAT DO WINDOWS. With the user interface set up, it's time to deploy the sensor network to do real work. Under a window in the lab, Rhee installs a node equipped with temperature and humidity sensors (4). The node keeps tabs on the window's performance: how much heat is lost, how much moisture leaks through. In an early application, says Rhee, window and door manufacturers are installing networked sensors in condominiums for warranty protection and checking them remotely using cell-phone modems and a local computer.

As a step toward automated building maintenance, Millennial Net is making sensor nodes communicate with a specially modified thermostat (5). The thermostat is equipped with a tiny computer and acts as central command. "Eventually," says Rhee, "thermostats will be integrated with wall sensors" to regulate room temperatures, detect insulation problems, and save energy.



6

7

6-7. HITTING THE ROAD. An advantage of small, low-power nodes is that they're mobile. To monitor shipping conditions en route to a supplier—important for perishables like meat, dairy goods, and medicines—a sensor node in a protective white case can be mounted in the back of a truck, measuring temperature and humidity every few minutes (6). Upon arrival at the loading dock, the node sends its tracking history to a fixed node on the wall (7). This node is connected to the receiving company's computer, which stores a detailed record.

Wireless sensor networks are still a fledgling business. Applications continue to be refined, says Rhee, but "putting more products on the market" will create the framework for new uses. If it's successful, his company stands to lead the way to a more efficient and better-networked world.

Where's My Job?

BY CORIE LOK | Photograph by David Deal

DEBORAH WINCE-SMITH

POSITION: President, Council on Competitiveness

ISSUE: "Offshoring" of high-tech jobs. Many companies have begun moving programming and engineering jobs overseas to lower-wage countries like India and China, following the trend set 20 years ago in manufacturing. What does this mean for U.S. leadership and competitiveness in technology?

PERSONAL POINT OF IMPACT: Helped the council, a nonpartisan coalition of industrial, academic, and labor leaders, launch its National Innovation Initiative to devise ways the United States can stay ahead of emerging global competitors

TECHNOLOGY REVIEW: IBM and other high-tech companies have recently drawn headlines by moving white-collar programming jobs overseas. Does this mean that the United States is losing its dominance in technological innovation?

DEBORAH WINCE-SMITH: No. In fact, if you look at the types of jobs that IBM is outsourcing, these are IT jobs, but they are not at the cusp of technological innovation. They are much more associated with the back-room operations, such as customer support and call centers. The really advanced work that IBM is doing, whether it's their new chip, or in high-end and high-performance computing, is in the United States. There's actually been a net gain in the number of jobs at IBM, and most of that new hiring will be in the United States.

TR: So this "offshoring" of technical jobs isn't a problem?

WINCE-SMITH: I do think there is cause for concern because so many American electrical engineers and software programmers have lost their jobs. These workers face some of the highest unemployment rates of any job sector in the U.S. Everyone says we'll train them to different jobs. Well, what jobs? If young people see that computer science and engineering are not stable professions with long-term job opportunities, they're going to be reluctant to go into these professions.

TR: What about more high-level design and engineering jobs? Couldn't they start moving overseas?

WINCE-SMITH: There are already a lot of so-called high-tech jobs, in design and engineering, moving overseas, particularly to China. The current level of programming and services offshoring to India is not yet at the level we might consider advanced technology, but certainly in the area of semiconductor design, engineering, and manufacturing, there's a very serious level of work being done in China. We're seeing a tremendous surge of U.S. companies participating in China in the manufacturing of very advanced systems. This type of offshoring, along with the advanced design and engineering that usually go with it, is a much more serious long-term competitiveness issue for the United States.

TR: What will the impacts of this type of offshoring be on U.S. competitiveness?

WINCE-SMITH: I think this offshoring is a very serious issue because it's really accelerating the emergence of nations like China and India as first-tier competitors in many of the most advanced, high-value economic activities. For example, the resources that China devotes to these types of activities are huge. Still, if anyone says that this is okay or not okay, we don't know. We don't have the data yet.

But one of the good things about this is that when China, India, and other countries begin to participate in this innovation activity in which there's a lot of economic value and employment at stake, I do believe that it will bring them more rapidly into the disciplines and business practices of developed economies, such as rule of law, transparency, and intellectual-property protection, most of which have historically been very weak in these nations. As China becomes more of an innovator, they're not going to be too keen on having their intellectual property stolen the way they've been appropriating other countries' intellectual property. There's been a tremendous amount of outright theft, where a U.S. design has actually showed up in a competing Chinese product. And it's not a zero-sum game. Prosperity and growth in standard of living in other regions and countries, including Southeast Asia and India, is in our and everyone's interest, because they empower consumers abroad to buy U.S. products and services.

TR: What's driving this movement?

WINCE-SMITH: The trend is part of globalization, there's no question. In the case of China, it's not only a huge market in the future, but because so much original work is being done in China, many companies feel that they have to participate in the innovation that's occurring there. Cost is also a driving factor. The Chinese government has provided many incentives to these firms. The cost of doing business in the United States is very high now. And China and India have some educated, talented people who earn considerably less than their American counterparts. Over half of all the U.S. graduate students in engineering are not Americans, and more and more of them are going home.

TR: High-tech manufacturing—as opposed to design work—has been happening overseas for a while. What are the implications for U.S. competitiveness on this front?

WINCE-SMITH: I don't think it's serious for your basic computer chip and other mass-produced commodities. But we do not want to lose the capability in the United States for the most advanced manufacturing of very complex systems, because that is directly related to the innovation process. In the course of manufacturing, you often create an innovation that takes you to the next generation. I'm concerned about the strategic implications of our very advanced microprocessors—those types of components that really differentiate a product—all being manufactured outside of the U.S.

TR: What should the U.S. do to stay ahead?

WINCE-SMITH: We want to ensure that we have skilled people at the forefront of design and engineering in the United States. We need to have more of our young people go into math, science, and engineering. We need to ensure that we have strong federal investment in the knowledge enablers of the future—in the mathematical, physical, and material sciences. There's been an imbalance in that investment, with the life sciences receiving favor for many years. Life sciences are important, but innovation there depends on investments in the physical sciences, too.

We need a regulatory environment, both at the national and state levels, that encourages and rewards entrepreneurial activities and doesn't impede our ability to create new businesses and see them flourish. One example is our product liability laws. As they stand, they are really anti-innovation. A whole set of requirements puts the burden of damages all the way back onto the first supplier, even if someone further up the chain was responsible. Also, many incentives are given to U.S. companies to relocate their operations to developing countries. That's good because we want to bring up the standard of living of the world and not have huge disparities in wealth, but at the same time, it almost makes the U.S. outpriced in some ways. So perhaps the U.S. can provide tax incentives to its own companies to stay in the U.S.

TR: In the long run, does it really matter where innovation comes from?

WINCE-SMITH: The only way the U.S. can maintain its standard of living and quality of life, and then ultimately, our security, is through productivity growth—and that depends on innovation capacity. We can't compete on low-cost labor, on natural resources, on standardized products. The products and services and capabilities that are going to come out of the research being done today in our universities, in our labs, and in industry are going to be huge wealth generators in the years ahead. We want the U.S. to be in a leadership role in those new industries of the future. And at the same time, we need to be prepared to capitalize on cutting-edge innovation wherever it occurs. That requires a sea change in approach and attitude for the United States, which has traditionally seen itself as the unrivaled leader in virtually every field. TR

Nano Writing

BY CORIE LOK

THE RELENTLESS PURSUIT of smaller components for everything from electronics to medical devices is making nanotechnology increasingly attractive to manufacturers. But one of the biggest challenges in the field is finding a cheap, easy, and fast method for building things on an extremely small scale.

One possible solution is dip-pen nanolithography, which a Northwestern University startup called NanoInk is commercializing. The technology, pioneered in 1999 by Chad Mirkin, a chemistry professor at Northwestern and NanoInk's founder, uses microscopic tips coated with a material that is deposited as "ink" on a surface. The approach makes it possible to "write" with a wide range of inks—metals, DNA, proteins—on an equally wide range of surfaces, such as silicon, glass, or metal. "We have total flexibility of inks and surfaces, which makes dip-pen nanolithography very attractive," says Cedric Loiret-Bernal, the company's president and CEO.

Founded in 2001, NanoInk is now raising between $20 million and $30 million for its third round of venture financing. In work that will be key to its commercial viability, NanoInk is scaling up the technology so that more than a million tips are writing at once, which should make the technique fast enough for manufacturing applications. Loiret-Bernal says he hopes to form collaborations this year with makers of computer chips, flat-screen displays, and gene and protein chips—glass wafers with hundreds of thousands of proteins or pieces of DNA attached to them, which are used in medical research, drug development, and medical diagnosis.

NANOINK

HEADQUARTERS: Chicago, IL

UNIVERSITY: Northwestern

INVESTMENT RAISED: $13 million

LEAD INVESTORS: Lurie Investments, Galway Partners

KEY FOUNDER: Chad Mirkin

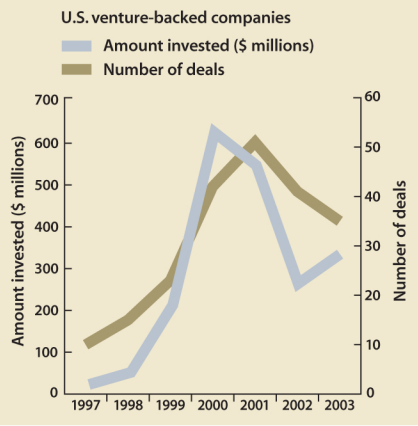
The technology's biggest prize, however, would be its use in microchip fabrication. NanoInk says dip-pen lithography can make chip features as thin as 15 nanometers, while the present-day method of making chips, photolithography, can barely fabricate features 65 nanometers wide. For now at least, dip-pen lithography is far too slow to compete with photolithography for the mass production of microchips themselves. But an initial application for NanoInk is the repair of masks, the thin pieces of glass that carry the patterns that are etched onto silicon wafers. Masks—a $2.9 billion annual market—cost $25,000 to $100,000 apiece to make, and many end up with defects. More than half of the flawed masks aren't repairable and are thrown out. Loiret-Bernal says the precise control offered by dip-pen lithography could make it a versatile and cost-effective method of repairing these masks. And eventually, with multiple tips writing at once, the technique could be used to make the masks in the first place, he adds.

Dip-pen lithography achieves its ultraprecision by placing tips coated with the material to be deposited—the pen's ink—within a few nanometers of a surface; a small water droplet condenses from the air and acts as a transport channel for the ink, allowing it to diffuse down to the surface. NanoInk's device boasts a precision unrivaled by other nanofabrication methods, says Mirkin, who is also the director of Northwestern's Institute for Nanotechnology. "It's a quantum leap in terms of capabilities," he says.

The hang-up, however, has been its speed, which is limited by the number of tips that can be used at once. Mirkin's work "is impressive," says Calvin Quate, an electrical engineering professor at Stanford University. "But the real test must await scaling to larger areas with parallel arrays." To tackle this challenge, NanoInk has recently developed a prototype with 1.3 million pens. Still, Mirkin points out that his dip-pen method isn't meant to compete with photolithography and its high speed. For applications such as mask repair and gene chip fabrication, high speeds aren't as important as the high accuracy and range of materials that dip-pen lithography offers, says Mirkin.

With a number of other nanofabrication methods emerging, NanoInk hopes its dip-pen technique will become one of the preferred tools in nanotechnology—and that along the way, it will write a new page in the history of manufacturing.

VENTURE FUNDING IN NANOTECH



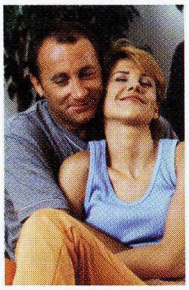
SOURCE: VENTUREONE (FUNDING)

NANO MANUFACTURING TOOLS

COMPANIES	TECHNOLOGY
Kovio (Sunnyvale, CA)	Liquid embossing to directly print patterns on chips
Molecular Imprints (Austin, TX)	Nanoimprint lithography for making chips
Nanonex (Monmouth Junction, NJ)	Nanoimprint lithography for making chips
Rave (Delray Beach, FL)	Photolithography-mask repair using atomic force microscopy

Clean your air silently for *HALF* the price!

Tests show the powerful Silent Surround Air Ionizer cleans your air with more Ionic power for half the price!



According to the Environmental Protection Agency, the air inside your home can be up to 10 times more polluted than the air outside. Most of our homes and offices are now sealed from fresh air so indoor pollutants are kept in while natural air cleansing agents are kept out. The EPA informs us that 6 out of 10 homes and buildings are "sick", meaning they are hazardous to your health as a result of airborne pollutants. Health problems relating to this phenomenon are real—Asthma cases have increased by more than 100% since 1976. It's time to put an end to your own personal air pollution problem.

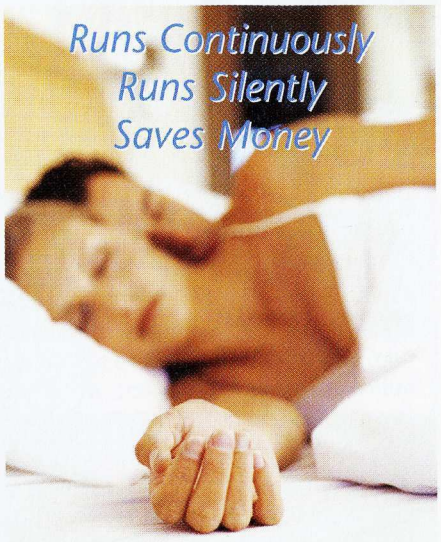
"It's so quiet I kept checking to be sure it was on. However, as the afternoon wore on, I knew for CERTAIN that it was on because in ONE AFTERNOON, my sneezing and running eyes have stopped! I vacuum daily because I am so allergic to dust. However, all the vacuuming in the world has not produced the results that one afternoon of Surround Air has."

—J. McNally, Mass.

How to Clean the Air inside of Your Home

Our goal was to find the most scientifically advanced air cleaning technology and build it for an affordable price. Well, we believe that we have succeeded beyond our wildest dreams. In a 16' x10' room, the breakthrough Surround Air was able to remove 99.2% of all particles that were .3 microns or larger. This allowed us to capture most pollen, cat dander, molds, fungus, dustmites and allergens that can lead to significant health problems.This test showed far better air cleaning results for the Surround Air, than for the other popular ionic cleaner on the market...*which costs twice as much!*

How were we able to achieve such great results? We used 16 stainless steel ion producing needle-points to create a much larger negative ion count. Plus we were able to create the "silent fan" technology that circulates more air through the cleaning grid while operating in complete silence—you can even run the Surround Air while you sleep. We were able to do all of this while using 40% less electricity thus reducing your operating costs.



There are no Expensive Filters to Change

Just wipe off the collector plate every 2-4 weeks and your air will be instantly cleaner and healthier in your home or your office. It will even reduce common household odors.

Cleaner Air for 60 Days

Try the Surround Air for 60 Days. If you are not breathing better, sleeping better and if your house doesn't smell better, simply return the Surround Air for a full refund of the purchase price.

- *Silent*
- *No Expensive Filters to Replace*
- *Traps Allergens and Bacteria*
- *½ the Price of the "other" brand*

Not available in stores.

Call now to take advantage of our special direct offer.

Surround Air Ionic Air Filter

Three Easy Payments of $49.50 +S&H.

Promotional Code SAF115-01

Please mention this when you call.

Toll-Free 24 hours a day

800-482-9147

To order by mail, please call for details.

We can also accept your check by phone.

NEXTTEN
products for your next ten years.

14101 Southcross Drive W.
Dept. SAF115-01
Burnsville, Minnesota 55337

For fastest service, call toll-free 24 hours a day 800-482-9147

See more innovative products at ***www.nextten.com***

SPAM FILTERS

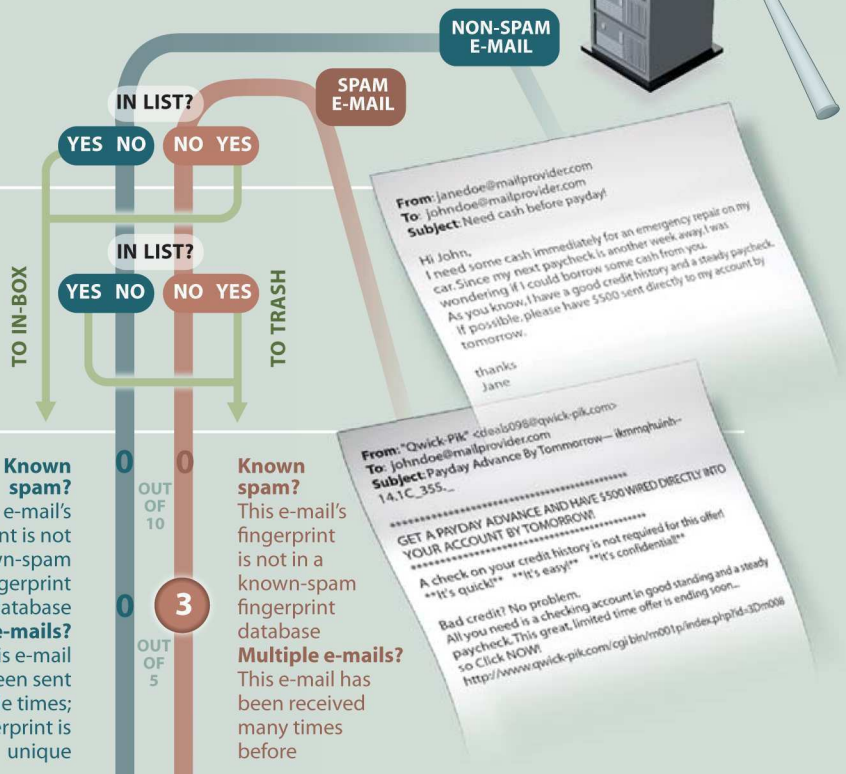
In 2003, nearly half of all e-mails were identified as spam, according to the Radicati Group, a research firm in Palo Alto, CA. There are eight to 10 basic techniques for filtering spam, which can be used in combination. Some filters render a simple "trash" or "keep" verdict; others assign points that represent an e-mail's likelihood of being spam. Here's one example of how different filters work together to put spam in its place. **TEXT AND ART BY 5W INFOGRAPHIC**

1 WHITELIST

A list, maintained by the user, of trustworthy addresses or domain names. Whitelisted e-mails go directly to the user's in-box.

2 BLACKLIST

A list of addresses and domain names that the user wants blocked. The list can be maintained at the mail server or on the user's computer.



3 FINGERPRINT

An algorithm assigns all characters in an e-mail numeric values, which it uses to calculate a numeric representation. This "fingerprint" is checked against a database of known spam fingerprints. The algorithm also accounts for whether an e-mail is identical to others received multiple times—a good indication of spam.

Known spam? This e-mail's fingerprint is not in a known-spam fingerprint database
Multiple e-mails? This e-mail has not been sent multiple times; its fingerprint is unique

0 OUT OF 10
0 OUT OF 5

Known spam? This e-mail's fingerprint is not in a known-spam fingerprint database
Multiple e-mails? This e-mail has been received many times before

4 HEURISTIC

A heuristic filter checks e-mail against a list of spamlike keywords and phrases. The more such words or phrases are found, the higher the e-mail's score.

Suspicious phrases:
1. "Need cash before payday!"
2. "Need some cash immediately"

2 OUT OF 10

Suspicious phrases:
1. "**It's quick!**"
2. "**It's easy!**"
3. "**It's confidential!**"
4. "Click NOW!"
5. Random characters:"ikmmqhuinh--14.1C_355._"
6. "Bad Credit?"
7. "limited time offer"

5 BAYESIAN

The filter is trained by the user, who categorizes received e-mails as spam or not-spam. Then the filter assigns probability values to each "token"—a word, a phrase, a symbol, or HTML code—based on how often it occurs in spam as opposed to regular e-mails. An e-mail's score is an average of the token scores.

Bayesian spam probability: **48 percent**

5 OUT OF 10

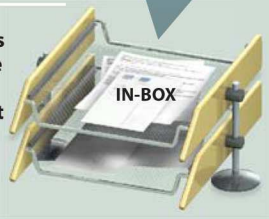
Bayesian spam probability: **80 percent**

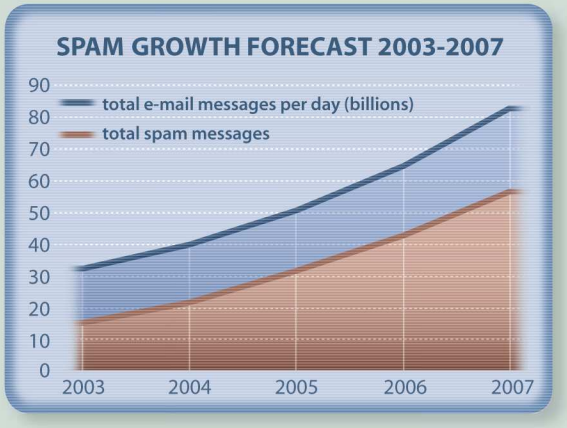
SAMPLE TOKENS	TIMES FOUND IN GOOD E-MAILS	TIMES FOUND IN SPAM E-MAILS	PROBABILITY VALUE ASSIGNED
credit	24	201	**89 percent**
!**	47	89	**65 percent**
quick	36	147	**80 percent**

TOTAL 7

TOTAL 18

The points from filters three through five are totaled for an overall score. The user can set the threshold above which an e-mail will be considered spam.





SOURCES: ACCELERATION, MXLOGIX, RADICATI GROUP

Home Is Where the Server Is

YOU'VE GOT YOUR HIGH-SPEED INTERNET CONnection, you've wired the house with high-speed cable, and you've installed, or are seriously contemplating, a wireless LAN. What's next? The answer is simple: you set up a home server. ■ If you work at a company with a network, you're familiar with the concept. A corporate server is a company's heart and soul: it's the e-mail hub and repository of important documents. It is where companies keep their crown jewels.

Unfortunately, the corporate server requires a substantial support staff. It's the computer that renders every desktop unusable when it crashes, and it's the ultimate target of hacker attacks. With all of these problems, why would any sane person want to have one at home?

Well, I've had a server in my basement since 1995, and frankly, I wouldn't want to live without it. Always running, my server holds my personal files, my music collection, and all of the digital data that I've been building up over the past 20 years. The server also mirrors the data that's on my two laptops and my two computers at MIT, keeping everything properly synchronized, and it automatically backs itself up. I can also log in remotely and get an important file if I happen to be at a friend's house. It's easy to lose your data if you keep it on a single computer. My server gives me automatic redundancy—and that safety net has saved me from many data disasters.

The server secures my data in another way, too: it's bolted into a rack, and that rack is bolted onto the floor. I've heard too many stories of people who have had computers stolen and lost all the data they contained. If my house is burglarized, it's unlikely that the thief will take the time to unbolt that box in the basement.

Of course, there's more to a home server than shared files and folders. The word "server" actually has an ambiguous meaning here: it refers both to the computer itself and to the programs that provide service to other machines. For each different service, the machine runs another program. The machine in my basement runs dozens, which means it is providing a range of services far beyond storing my data.

I've had a server in my basement since 1995, and frankly, I wouldn't want to live without it.

The most important program my system runs is the mail server. Like those at a growing number of businesses and universities, my server speaks IMAP—the Internet Message Access Protocol. Unlike the Post Office Protocol (POP) used by most Internet service providers, IMAP keeps all of my mail on the server and downloads a copy of each message only to whatever desktop machine I happen to be using. When I delete a message, that action happens both on my desktop and on the server at the same time. And if I'm using my laptop, my mail program remembers all of those actions and transmits them back to the server when it's back on the network. This means that the mailboxes on all of my various laptops and desktops are kept perfectly synchronized.

I once made a video of my kids, with my wife playing piano. I turned it into a high-fidelity QuickTime file and then set up a streaming server to let my parents watch the video over the Internet. I know a DJ who set up a streaming MP3 server to play the same music on every computer in the house—and to share his live spinning with his friends. I have tens of gigabytes of information on my Web site; renting that much storage from a hosting company could cost $100 a month.

Fortunately, home servers are easier to maintain than corporate servers. In the business world, the people using the server never quite know what sort of changes or upgrades are being done by the administrators. This is where most of the angst and confusion come from: poor human-to-human communications. When you run your own server, these communication problems go away.

Both Linux and Windows XP make great server operating systems; of the two, I recommend Linux. The problem with XP is that most of the add-ons you might want to run can end up costing a lot of money, while with Linux most of these add-ons (things like Web mail or an SQL database) are free. Linux is also much more reliable. And while servers should have huge hard drives, they don't need the fastest CPUs or a ton of memory. My server has 500 gigabytes of disk space but just 512 megabytes of RAM and a 600-megahertz processor that's nearly three years old. You can put an entire system together with a bargain-basement PC for about $400. Indeed, a Mountain View, CA, company called Mirra has done just that, complete with automatic backup software for Windows-based PCs.

If you're not up to running your own server, but you have several desktop systems, you can network them together and use the basic file and print servers that are built into the Windows and MacOS operating systems. The problem with using somebody's desktop as a household server is that the network services stop working every time that machine boots. A few months of that, and soon you'll want your own server, too. TR

Simson Garfinkel is an incurable gadgeteer, an entrepreneur, and the author of 12 books on information technology and its impact.

More LUX Less Bucks!

Bring the revolution of Natural Sunlight Technology into your home for half the price of the competitors

If you use standard light bulbs, the lighting in your home leaves you in the "dark ages". Standard incandescent bulbs and traditional fluorescent bulbs do not provide the white light necessary for many of your favorite indoor activities. Reading, sewing, and crafts require you to see details and accurate colors. And as we age, our eyes need more light to focus clearly. But your current bulbs, which emit yellowish or greenish light, leave your eyes tired and strained. Well, we looked to the sun for inspiration and developed the SunWhite lamp. And we priced it much lower than all of the other "daylight" lamps on the market. You can now bring the sun indoors for about half the price that you'd expect.

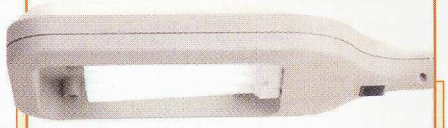
How did we do it. First we used a technologically advanced bulb that contains rare earth phosphors that emit a purer whiter light than conventional bulbs. These amazing bulbs produce about 2800 lux in light output creating about 50% more light output than a standard 100 watt bulb from G.E.. And we do it efficiently with only 27 watts of power that allows you to pay for this lamp in electricity savings in about 2 years of regular use. To make the value even better, this bulb lasts for 5000 hours or more than twice as long as the best selling bulb. More lux...less bucks!

Don't get burned. We made our bulb cool to the touch. Much of the electrical energy transferred to conventional bulbs is wasted as heat. You can even burn your hands or burn a lampshade with old traditional bulbs. But not the SunWhite bulb. It's cool to the touch even after being lit for hours.

Finally we are offering such a low price because our factory boss wants to be the leader in this new technology. He's invested millions in factory machinery to be the most efficient manufacturer of full spectrum lighting. He believes that our SunWhite technology will overwhelm the current lightbulb business and he wants to be the leader in "sunlighting". So don't get ripped off by paying $99-$159 for "sunlighting" technology.

We are so sure that you will love this lamp that we are offering a 60 day money back guarantee. If this light doesn't brighten up your world, make your eyes feel better and even lift your mood, just send it back for a full refund of the purchase price. We can offer this extended guarantee because so few of our lamps get returned to us. We have sold thousands of lamps and its extremely rare to get a return. Don't strain your eyes for one more day.

NOW at the NEW LOW PRICE of $69.95!



- **50% more light output than a standard 100 watt**
- **Bulb has 5,000 hour life.**

Research has shown that full spectrum lighting can:

- Improve concentration on schoolwork.
- Ease the winter blues.
- Ease eyestrain.
- Render colors much more accurately for artists, knitters and needlepoint.

Not all lights are created equal!

GE Reveal™	*SunWhite*
1352 Lumens	2800 Lumens
100 Watts	27 Watts
750 Hour life	5000 Hour life
Burns Hot to the touch	Cool to the touch

Not available in stores.

Call now to take advantage of our special direct offer.

SunWhite Full Spectrum Floor Lamp
~~$129.95~~ **$69.95 + S & H.**

Promotional Code FSL129-01
Please mention this when you call.

Toll-Free 24 hours a day

800-482-9143

To order by mail, please call for details.

We can also accept your check by phone.

NEXTTEN
products for your next ten years.

14101 Southcross Drive W.
Dept. FSL129-01
Burnsville, Minnesota 55337

For fastest service, call toll-free 24 hours a day 800-482-9143

See more innovative products at ***www.nextten.com***

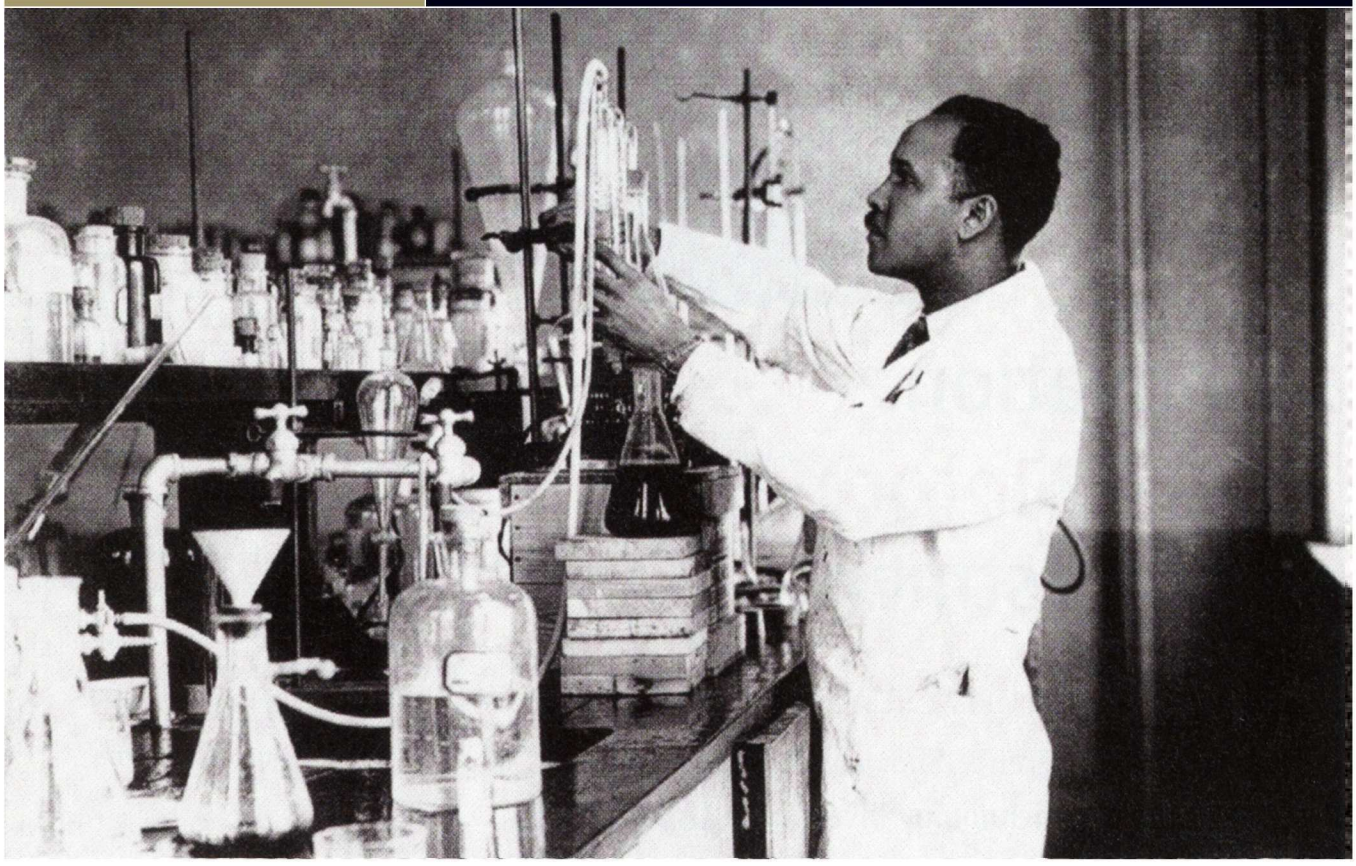
INDEX

People and organizations mentioned in this issue

CLASSIFIEDS

CAREERS ADVERTISING
For more information on display advertising in this section, contact:
Paul Gillespie 617-475-8004
paul.gillespie@technologyreview.com

CLASSIFIED ADVERTISING
For more information on classified advertising, contact:
Amy McLellan 617-475-8005
amy.mclellan@technologyreview.com
Rates are $75 per line with an average of 50 characters and spaces per line.
Deadline is 8 weeks before issue date.



Born Chemist

Despite many obstacles, the irrepressible Percy Lavon Julian became a successful drug innovator. BY LISA SCANLON

In 1916, 17-year-old Percy Lavon Julian, the grandson of a former slave, journeyed from Montgomery, AL, to Greencastle, IN, to begin his college education at DePauw University. In spite of his scant preparation—insufficient public education available to African Americans in Alabama made it necessary for him to take remedial high-school classes while at DePauw—the chemist graduated as class valedictorian. He went on to synthesize both a drug for the treatment of glaucoma and cortisone for rheumatoid arthritis.

Despite Julian's academic success, his professors informed him that they couldn't secure him a position at a graduate school or an industrial lab because of his race. Instead, Julian became a chemistry instructor at Fisk University in Nashville, TN; two years later, he went to Harvard University to study biophysics and organic chemistry. He received his master's degree in 1923 but again was denied a faculty position. After teaching at West Virginia State College and Howard University, he received a grant in 1929 from the Rockefeller Foundation to get his PhD. He chose to attend the University of Vienna in Austria, where he developed a passion for the chemistry of natural products.

Julian returned to DePauw in 1932 with a colleague from Vienna to head a new research program for undergraduate organic-chemistry students. One problem the group worked on was the synthesis of physostigmine, a drug used to treat glaucoma that at the time could only be obtained from the Calabar bean. Anxious to hold onto funding during the Depression years, Julian and his team raced against a University of Oxford group to synthesize the rare drug. Julian succeeded in 1935 and became internationally famous—yet DePauw's board of trustees still refused to grant him a professorship.

Frustrated, Julian left academia the next year to become research director for soya products at Chicago-based Glidden. There, he made perhaps his most important discovery. In 1948, Julian heard that scientists at the Mayo Clinic had discovered a substance that successfully treated rheumatoid arthritis. Since it was a steroid, the class of chemicals that Julian specialized in, he hurried to create it synthetically. Within a year, he had succeeded; his work was largely responsible for making hydrocortisone widely available and affordable. Over the next 25 years, Julian founded two research organizations and received many patents. He kept ties with DePauw, the school that originally couldn't find him work; in the years before his death in 1975, he served on the board of trustees. TR

COURTESY OF DEPAUW UNIVERSITY

Technology Review (ISSN 1099-274X), Reg. U.S. Patent Office, is published monthly, except bimonthly in December/January and July/August, by the Massachusetts Institute of Technology. Entire contents ©2004. The editors seek diverse views, and authors' opinions do not represent the official policies of their institutions or those of MIT. Printed by Brown Printing Company, Waseca, MN. Periodicals postage paid at Boston, MA, and additional mailing offices. Postmaster: send address changes to *Technology Review*, Subscription Services Dept., PO Box 420005, Palm Coast, FL 32142 , or via the Internet at www.technologyreview.com/customerservice/. Basic subscription rates: $34 per year, Canadian residents add $10, other foreign countries add $30. Publication Mail Agreement Number 40621028. Send undeliverable Canadian copies to PO Box 1051, Fort Erie, ON L2A 6C7. Printed in U.S.A. ABC audited


On time for the next shift in toy land.
Toys"R"Us® might just have the largest toy inventory challenge in the world. A challenge they meet every day with help from their technology partner, HP. To do this, HP software and high-performance servers see to it that every toy in every store is constantly tracked and managed. So if one hundred Geoffrey® Giraffes leave the stores, one hundred new Geoffrey Giraffes arrive back on the job, lickety-split. www.hp.com/plus_toysrus
toys"r"us
+
hp
= everything is possible
hp
invent
©2003 Hewlett-Packard Development Company, L.P.